ABSTRACT

Thesis Title:	SUBAQUEOUS SOILS OF SOUTH RIVER, MARYLAND: SOIL-LANDSCAPE MODEL EVALUATION
	Cedric Evan Park, Master of Science, 2021
Thesis directed by:	Professor Martin C. Rabenhorst, Department of Environmental Science and Technology

The way soils form, their distribution on the landscape, and their interactions with their ecosystems must be understood if they are to be managed well. Our incipient understanding of subaqueous soils limits successful management, but recent research efforts have sought to address this problem. The goal of this study was to evaluate the protocols for describing, characterizing, classifying, and mapping subaqueous soils. To this end, a subaqueous soil-landscape model (Wessel, 2020) was used to predict the distribution of soils in South River, a western shore Chesapeake Bay subestuary. The soils of South River were surveyed, and the observed soils were compared to the predictions. The model provided significant positive guidance for mapping subaqueous soils, confirming that a pedological approach is useful in subaqueous settings. Pedological data were used to generate a subaqueous soils map for South River and make recommendations to refine the model. Protocols related to soil porewater halinity and mineralogy were also investigated.

SUBAQUEOUS SOILS OF SOUTH RIVER, MARYLAND: SOIL-LANDSCAPE MODEL EVALUATION

by

Cedric Evan Park

Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
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Advisory Committee:
Professor Martin C. Rabenhorst, Chair
Associate Professor Brian A. Needelman
Associate Professor Lance T. Yonkos

Dedication

To my inexpressibly wonderful wife, Ellie, who has shown me more love and patience than I could ever ask for.

And to my incredible family, without whose love and support I wouldn't have made it to graduate school, let alone finished it.

Acknowledgements

"Every good and perfect gift is from above, coming down from the Father…"

James 1:17

I first acknowledge my Lord and Savior, Jesus Christ. I am ever conscious of my predilection to self-centeredness, conceit, and resentment, so I thank Him for His forgiveness and redeeming love, and for teaching me humility, gratitude, and graciousness. The people who have surrounded me and helped me accomplish this thesis have indeed been a gift. A gift that I believe is God-given. I think most of us don't contemplate grace very often, but if you want to know what it feels like to receive it constantly, do grad school with these people around you.

First and foremost, I am deeply grateful to my advisor Dr. Martin Rabenhorst, who gave me my first opportunity as a scientist, encouraged me to pursue graduate school, and guided me in that pursuit. His mentorship has been invaluable to this project, my development as a scientist, and my personal growth. I am also grateful to my committee: Dr. Brian Needelman, who taught me that you can hold yourself to a high standard professionally and personally and also be patient with yourself; and Dr. Lance Yonkos, whose expertise helped me get my nose out of the dirt a little bit.

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I would like to thank the outstanding scientists who contributed to my development: Rob Tunstead and Philip King, who taught me about soil survey and patiently answered my questions; and Dr. Mark Stolt, who taught me about soil taxonomy and halinity.

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There were times when graduate school made me think not of James 1:17, but rather of James 1:2. For being there for me in those times, I thank my matchless family and friends. Jon King, Eric and Virginia Schrock, Isaac Vineyard, and Kenny Camacho, you are who I want to be like when I grow up.

If I were to name all who supported me scientifically and personally through this journey, the list would go on and on. So allow me to say once more, for all, thank you, from the bottom of my heart.

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Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

"He stooped sometimes and gathered some of the earth up in his hand and he sat thus and held it in his hand, and it seemed full of life between his fingers."

Pearl S. Buck, *The Good Earth*

1.1 Background

Soil mapping is vital to prudent management of soil resources and is accomplished by observing the landscape and understanding the factors that have changed it over time. With these factors in mind, pedologists can predict the types of soils present in a landscape and how they will be arranged. By understanding how soils are arranged on a landscape, we can identify the optimal use for an area of land. The relationships between soils and landscapes in upland settings have been studied extensively; they have been codified in the soil-landscape paradigm, which recognizes that the expression of soil characteristics is related to environmental factors (climate, relief, organisms, and parent material) in consistent, predictable ways, and therefore the distribution and extent of soils can be inferred from such factors (Hudson, 1992). By contrast, there is a relative dearth of knowledge of the relationship between landscapes and subaqueous soils (soils that have water on the soil surface continually). This lack of understanding limits best management in estuarine systems, including Chesapeake Bay.

From the arrival of paleo-Indians in the region 10,000 years ago, to the expeditions of Giovanni da Verrazano and John Smith, to the present day, Chesapeake Bay has been a unique resource of ecological, cultural, and economic significance. Named *Chesepiooc* ("great shellfish bay") by the Algonquin people, it has long served as a home and a gathering place for the Indigenous people of this continent (Torben et al., 2014). In the early days of European settlement, it was a bountiful frontier that allowed pioneers to survive in the "new world" (Smith & Thompson, 2007). Now, the Chesapeake Bay watershed is home to more than 18 million people, and its ecosystem is beset by problems caused by pollution, overharvest, agricultural runoff, and urban and suburban development (CBP, 2021b). Myriad projects, conducted by a host of academic institutions, non-profit organizations, and state and federal government agencies, have been undertaken to identify and enact solutions that address these issues. One of the many efforts to restore the Bay's health and promote responsible management is the study of subaqueous soils. Subaqueous soils are a vital part of the estuarine ecosystem that interact with the water column, influence nutrient fluxes, and provide substrate for vegetation, oysters, and clams (Bradley & Stolt, 2006; Koch, 2001; Still, 2016). Nevertheless, they have not received the same scientific attention as water quality, submerged aquatic vegetation, or fisheries, to the detriment of Chesapeake Bay conservation and management.

Subaqueous soils have been neglected in Chesapeake Bay and other coastal ecosystems because subaqueous soil science is a relatively nascent, undeveloped branch of pedology. Traditionally, the core of our understanding of soil has been related to its function as a medium for plant growth – especially agricultural crops (Demas, 1998; Soil Survey Staff, 1975). In the 18th and 19th centuries, scientific research led to technical definitions of soil that undergirded that intuitive understanding (Dokuchaiev, 1948; Simonson, 1986; Tull, 1733). The substrate in shallow water settings was generally considered sediment, not soil, because it was not viewed as having the same capability to support plant life as upland soils. In the 20th century, there were several proposals to consider shallow water sediments as soils (Goldschmidt, 1958; Kubiena, 1948; Kubiena, 1953; Muckenhausen, 1965; Ponnamperuma, 1972), but they mainly focused on including these sediments in pedologically based classifications schemes. Historically, little work was done to characterize and map the sediments, and the prevailing pedologic, geologic, and ecologic view was that they were not soil.

In the 1990s, the pioneering work of George Demas initiated a renaissance in subaqueous soil research. He questioned why the proposals to consider subaqueous sediments as soils had been abandoned, and why the soil-landscape paradigm had not been applied in earnest to shallow water environments. His work demonstrated that subaqueous sediments exhibited horizons distinguishable from the initial geologic material due to pedogenic processes of additions, losses, transfers, and transformations (Demas & Rabenhorst, 1999). As a result, the definition of soil was revised in the 8th edition of *Keys to Soil Taxonomy* to include soils in shallow water environments (with water 2.5 meters deep) (Soil Survey Staff, 1998). Demas also tested the soil-landscape paradigm in shallow water environments, and, after identifying factors of subaqueous soil formation, adapted Jenny's soil forming state factor equation to accommodate subaqueous settings (Demas & Rabenhorst, 2001).

In the years following Demas's foundational work, soil scientists began conducting subaqueous soil surveys (Balduff, 2007; Bradley & Stolt, 2003; Ellis, 2006; Osher & Flannagan, 2007). Researchers delineated subaqueous landforms primarily based on bathymetry, then sampled on the landforms to learn what soils were present there. There were some hypotheses about soil distribution, but these early studies were mainly descriptive, not predictive.

These studies developed protocols for and helped demonstrate the usefulness of subaqueous soil survey. An early criticism of subaqueous soil science was that sedimentation and erosion altered bathymetry too frequently for subaqueous soil maps to accurate or useful for more than a few years. Bradley and Stolt's (2002) work in Rhode Island lagoons comparing new bathymetric data with older NOAA bathymetric surveys from the 1960s and 1970s demonstrated no significant differences between the datasets, even though the NOAA surveys were 40 years older. Their research demonstrated that subaqueous landforms are stable on a scale of decades, and that soil surveyors can use existing bathymetric datasets to delineate landforms instead of collecting it anew (a time-consuming process). In his study of Chesapeake Bay subestuaries, Wessel (2020) reinforced their conclusion when he found that direct bathymetric measurements did not differ dramatically from bathymetric surveys dating back to the mid-19th century. It is possible (maybe even likely) that subaqueous landforms in the US were more dynamic in the 18th century and early 19th century when European settlement and agricultural production was rapidly expanding. During this period, there was widespread clear-cutting of the forests that dominated the Mid-Atlantic region in order to clear land to cultivate tobacco. Gottschalk (1945) described this period with a simile of Biblical proportions, likening the sedimentation of the Susquehanna River to the desertification of Ur of the Chaldeans. In any case, the patterns of land management in the American colonial period led to intense erosion and high sediment loads entering Chesapeake Bay. Agriculture in the Mid-Atlantic region, however, declined after the American Civil War, which to some degree ameliorated the erosion of coastal plain soils (Daniels, 1987; Trimble & Crosson, 2000). Furthermore, the soil conservation efforts following the dust bowl period led to decreased erosion in the second half of the 20th century with presumably decreased sedimentation and infilling which has produced a relatively stable subaqueous landscape in Chesapeake Bay for at least 150 years.

In addition to demonstrating the usefulness and potential lifespan of subaqueous soil survey, studies have shown that subaqueous soil research helps improve coastal resource management, especially in relation to oyster aquaculture (Still, 2016), submerged aquatic vegetation habitat (Balduff, 2007; Bradley & Stolt, 2006; Ellis, 2006), identification of potential acid sulfate soils (Wessel & Rabenhorst, 2017), and use of dredged material (Cornwell, 2020; Staver, 2020).

Many subaqueous soil studies have taken place on the east coast of the United States, including in Maine (Osher & Flannagan, 2007), Rhode Island (Bakken & Stolt, 2018; Bradley & Stolt, 2003; Still, 2016; Stolt et al., 2011), Florida (Ellis, 2006), and coastal bays in New Jersey, Delaware, and Maryland (Balduff, 2007; Demas, 1998). More recently, Wessel (2020) conducted a study of subaqueous soils in Rhode River, a subestuary on the western shore of Chesapeake Bay. It was the first survey conducted in the Bay, which, considering its extent and ecological and economic significance, was long overdue. The study went beyond the descriptive surveys of the past and sought to predict the distribution of subaqueous soils. Whereas earlier researchers tacitly employed the soil-landscape paradigm, Wessel intentionally articulated the soil-landscape relationships in Rhode River and used them to develop a conceptual model of soil pedogenesis and distribution in western shore Chesapeake Bay subestuaries.

The Rhode River model is a developing concept to be used to predict distribution of soils in western shore subestuaries of Chesapeake Bay. The present study in South

River tested the usefulness of the Rhode River model and provided soils data to refine the model. South River was chosen as the location to test the Rhode River model because it shares many characteristics with Rhode River, facilitating comparison. Both subestuaries are underlain by glauconite-bearing geologic deposits of Cretaceous and Tertiary age; both are mesohaline (5–18 ppt halinity); both watersheds have similar land uses (forested land, urban/suburban residential areas, and agricultural land). Furthermore, surveying the subaqueous soils of South River is of interest because the river is utilized for commercial crabbing, charter fishing, and recreation, and because the upper part of the river is an oyster sanctuary (MD Department of Natural Resources, 2017).

1.2 Objectives

The overarching objective of this study is to advance the development of a unified framework for characterizing, classifying, and surveying soils. Historically, upland soils and aquatic sediments have been considered distinct entities with different paradigms of scientific investigation, but this present work aligns with a more recent perspective that the study of shallow water environments can be enriched by a pedological approach. By evaluating the usefulness of tenets of upland soil survey in estuarine settings, this work contributes one small step towards a unified understanding of the earth's surface.

The specific objectives of this study are:

1. To evaluate a conceptual soil-landscape model for western shore subestuaries of Chesapeake Bay by applying it to, and testing it in South River, and in so doing to generate a subaqueous soil inventory for South River.

2. To develop standardized methods for measuring, reporting, and classifying soil halinity

3. To investigate subaqueous soil mineralogy in South River and make recommendations for the mineralogy family classification requirements for subaqueous soils formed in glauconite-bearing sediments.

Chapter 2: Subaqueous Pedology and Soil-Landscape Model Evaluation in South River

2.1 Abstract

A subaqueous soil survey was conducted in South River, a mesohaline subestuary on the western shore of Chesapeake Bay. Initially, a draft soil map was created based on the Rhode River soil-landscape relationship model (Wessel, 2020), and then, in order to test the model, the soils of South River were sampled at 52 points along specified transects. The soils were described and classified, then the data were compared to the original mapping using a bootstrapping analysis approach. We concluded that the Rhode River model did provide significant positive guidance to generate a useful soil map. While it successfully predicted the distribution of soil material types, it did not address the presence of hypersulfidic materials, which were prevalent in South River soils, especially on terrace and channel landforms. A revised subaqueous soil map was created that incorporated the South River soil observations. These observations were also integrated into a refined soil-landscape relationship model for western shore subestuaries.

2.2 Introduction

2.2.1 Subaqueous pedology

In the past 25 years, soil scientists have forayed into shallow-water environments to conduct pedological research. One of the pioneers of this venture was George Demas, who became interested in the possibility of subaqueous pedology while working as a soil surveyor for the Natural Resources Conservation Service. His work demonstrated that the substrate in shallow-water environments satisfied the definition of soil. The material underwent soil forming processes of additions, losses, transfers, and transformations to develop soil horizons distinguishable from the initial material (Demas & Rabenhorst, 1999; Soil Survey Staff, 2014a). In addition to initiating a serious effort to explore subaqueous soil in the US, Demas also identified subaqueous soil forming factors analogous to those advocated for upland soils by Jenny (Demas & Rabenhorst, 2001; Jenny, 1941).

2.2.2 Soil-landscape paradigm

Demas's subaqueous soil forming factors facilitated the application of the soil-landscape paradigm in subaqueous environments. The soil-landscape paradigm underpins soil survey by recognizing that soil characteristics are distributed across a landscape in consistent, predictable ways because of certain environmental factors (namely, Jenny's soil forming factors, or, for subaqueous soils, Demas's soil forming factors). Therefore, if those environmental factors are understood, then the distribution and extent of soils can be inferred (Hudson, 1992). The soil-landscape paradigm allows soil surveys to be completed efficiently with selective and strategic soil sampling, rather than requiring random or grid sampling. In this way soil surveyors are able to "groundtruth" the paradigm they are using as they go (Indorante et al., 1996).

Early subaqueous soil surveys studied subaqueous soil forming factors and described the relationships between those factors and soil characteristics (Balduff, 2007; Bradley & Stolt, 2003; Ellis, 2006; Osher & Flannagan, 2007). Recently, Wessel (2020) conducted a study in Rhode River, a subestuary on the western shore of Chesapeake Bay, that described the relationships between subaqueous landforms and soils. The study, however, went beyond the older, descriptive studies and used soil-landform relationships as a conceptual model to predict soil distribution in an adjacent subestuary (Wessel, 2020). The present study is a further application and evaluation of the Rhode River soil-landscape relationship model within South River, a larger subestuary to the north of Rhode River.

2.2.3 Rhode River model

The conceptual soil genesis model proposed by Wessel describes a long, complex pedogenic history. The middle section of Chesapeake Bay, where Rhode River and South River are found, is underlain by the Aquia and Nanjemoy formations, which are glauconite-bearing marine deposits of Paleocene and Eocene age (respectively). Miocene and Quaternary formations were also deposited above these in the stratigraphic column in the ancient marine environment (Glaser, 2002). During periods of low sea level, most recently in the late Pleistocene epoch, the Miocene and Quaternary materials were eroded and the Aquia and Nanjemoy formations were exposed. They dewatered, consolidated, and underwent pedogenesis. Distinct subaerial pedogenic features including argillic horizons, iron oxide concentrations, and iron oxide-coated soil matrices developed (Wessel, 2020). As glaciers began to retreat 15–20Ka ago, sea level began to rise; approximately 8000 years ago, Chesapeake Bay took its modern shape when rising sea water overran the banks of the ancient Susquehanna river valley and flooded that portion of the coastal plain (Bratton et al., 2003). In the region of the present-day Rhode River, tertiary paleosols were truncated by wave action. As the wave-cutting front moved inland, suspended sediment began to settle out in the deepening subestuary. This process of truncation and deposition created subaqueous landforms that developed characteristic soil profiles. These soils were composed of several soil material types, which Wessel described in detail. Holocene sandy material is nonfluid or occasionally slightly fluid with coarse textures (fine sandy loam or coarser). Holocene fluid fine material is slightly fluid to very fluid with fine textures including silt loam, silty clay loam, clay loam, silty clay, and clay. This material is categorized as “mud” in the terminology of marine geologists (Folk, 1954). Organic material is generally muck (Oa) or mucky peat (Oe) in Rhode and West Rivers. Buried A material is dark in color and commonly contains root fragments. It generally has textures such as loam, sandy loam, loamy sand, or sand. This material once constituted the soil surface but is presently overlaid by Holocene sandy material or Holocene fluid fine material. Tertiary paleosols are divided into two material types – those with and those without iron oxide concentrations (Wessel & Rabenhorst, 2017).

These several material types constitute the major components of the subaqueous soils that developed in the Rhode River region. In the shallow parts of the subestuary, wave-cut platform landforms developed, where Holocene sands overlay truncated paleosols (Tertiary material with or without iron oxide concentrations). These were relatively high-energy areas, so only the heavy, coarse-textured scour-lag material settled out of the water column. As the water deepened and slope of the basin steepened (to approximately 5%), wave-built terrace landforms developed, where more Holocene sands settled out in thick, stratified deposits. In the deepest parts of the subestuary, channel landforms developed. These were low-energy areas, so Holocene fines were able to settle out of the water column and form thick, fluid deposits. Compared to other soils in South River, those on channel landforms were relatively high in organic carbon (1–3%) (Wessel, 2020).

In addition to the dominant platform-terrace-channel concept, the Rhode River model includes several other landforms. There are submerged tidal marshes adjacent to emergent marshes, where histosols or histic epipedons are expected below a mantle of Holocene sands. There are submerged shoal/saddles, which are similar to wave-cut platforms, except that they exist farther from shore, where they may have been islands that eroded, and typically have profiles with a mantle of Holocene sands over a truncated paleosol. The tidal creeks follow the platform-terrace-channel concept, but they are differentiated because the tidal creeks are smaller, narrower, and less energetic. They exhibit less paleosol erosion on the platform and mantles of Holocene fluid fines on the terrace.

Wessel proposed new soil series for the characteristic soil profiles he found in Rhode River and correlated them to landforms, creating consociation soil map units (meaning the landform was dominated by a single soil series). In this way, soils in other subestuaries could be predicted by first delineating subaqueous landforms, then mapping the corresponding soil series for each landform (Wessel, 2020).

2.2.4 Hyper- v. hyposulfidic materials

One of the most significant pedogenic processes that occurs in Rhode River and South River is the generation and accumulation of sulfide minerals. In estuarine environments, and other marine or brackish settings, the water provides a source of sulfate within marsh and subaqueous soils. The sulfate can become reduced to sulfide when sulfate-reducing bacteria (e.g., *Desulfovibrio desulfuricans*) utilize organic carbon under anaerobic conditions. The sulfide will react with ferrous iron present in the soil system and precipitate as a ferrous sulfide mineral. These minerals are often metastable but can include more persistent species such as pyrite. This process of forming and accumulating iron-sulfide minerals has been called sulfidization. If these sulfide-bearing materials become oxidized (such as following dredging), they can produce sulfuric acid, which may dramatically lower soil pH and generate acid-sulfate soils. This process, called sulfuricization, results in conditions that are toxic to many plants (Fanning & Fanning, 1989).

Because of the potential environmental hazards, there is interest in identifying sulfide-bearing materials in subaqueous soil surveys. In *Keys to Soil Taxonomy*, the term "sulfidic materials" is used to denote soil material that has an initial pH >4 and experiences a drop in pH of at least 0.5 units to a final pH <4 due to sulfide oxidation (Soil Survey Staff, 2014a). The *World Reference Base for Soil Resources* uses the term "hypersulfidic materials" to denote materials that are similarly defined, but also uses the term "hyposulfidic materials" to denote materials that contain inorganic sulfides, but do not acidify upon oxidation because of the material's neutralization capacity (FAO, 2014). In this study, soils were classified according to *Keys to Soil Taxonomy*, but the terminology of *World Reference Base* was also used. Where hypersulfidic materials are named, the materials satisfy the definition of sulfidic materials as written in *Keys to Soil Taxonomy*. This choice mirrors the terminology used in Wessel's Rhode River study, facilitating the comparison between soils in both study sites.

<u>The objectives of this study were:</u>

1. To generate a draft subaqueous soil map of South River by applying the Rhode River subaqueous soil-landform relationship model within the South River subestuary

2. To evaluate the usefulness of the Rhode River model for predicting soil characteristics and distribution within the South River subestuary
3. To revise, as needed, the soil landscape model for western shore subestuaries of Chesapeake Bay
4. To generate a subaqueous soil resource inventory (map) of South River

2.3 Methods

2.3.1 Study site

South River is a mesohaline subestuary on the western shore of Chesapeake Bay, in the Coastal Plain physiographic region of Maryland. The area of the river is approximately 2,000 ha, and its watershed is approximately 15,000 ha (MD Department of Public Works, 2020). It was chosen as the study site because it is immediately proximate to Rhode River, and it is underlain by similar, glauconite-bearing, tertiary-aged geologic materials (Fig. 2.1). Also, the sampling equipment typically used in subaqueous soil investigations (that was utilized in the Rhode River study and available for the present study), is most useful in water depths less than six meters; a spatial analysis conducted in ESRI ArcMap (v. 10.4; ESRI Corp., Redlands, Calif.) showed that 97.9% of the South River estuary was shallower than six meters (Table 2.1).

Figure 2.1. Study site: South River

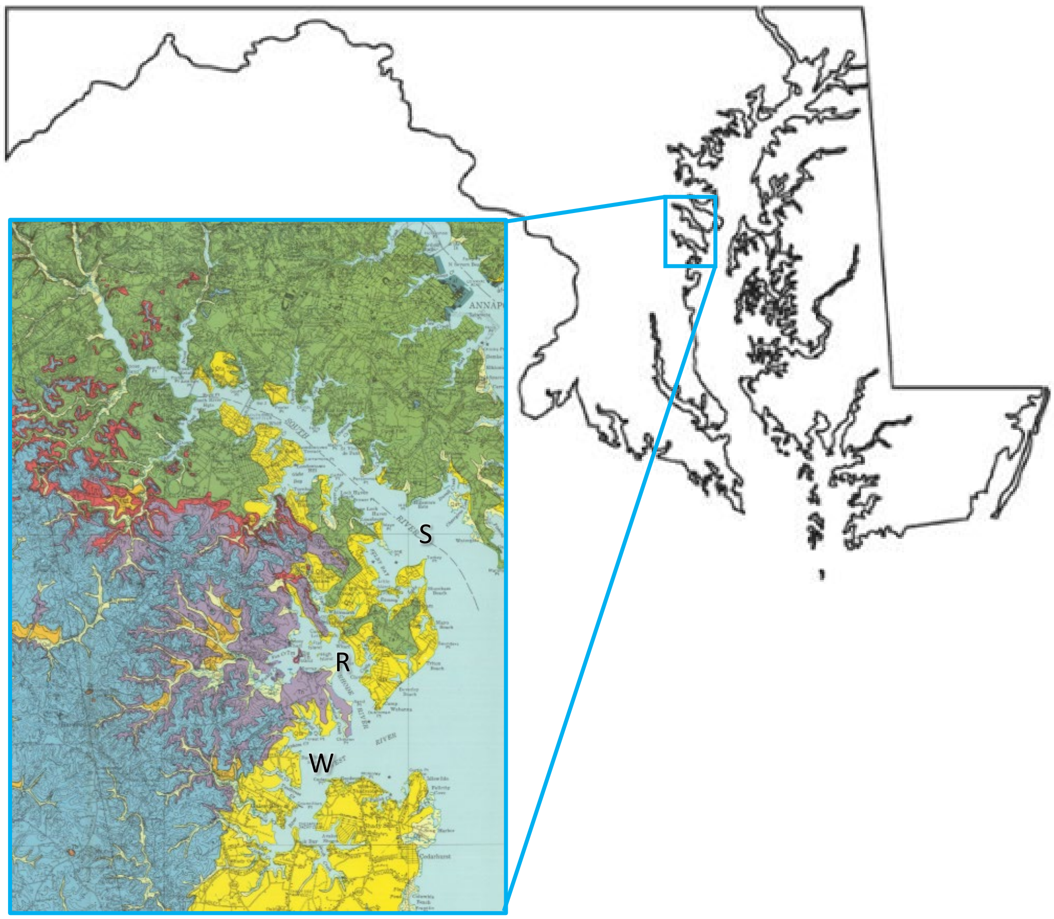


Fig. 2.1. The study site, South River (blue box), is located in Anne Arundel county, Maryland. *Inset*: The Anne Arundel County geologic map detail (Glaser, 1976) shows South River – S (northernmost), Rhode River – R (middle), and West River – W (southernmost). Wessel (2020) surveyed Rhode River and West River, which are underlain by the Nanjemoy formation (shown in purple). South River is underlain by the Aquia formation, which is a similar, glauconite-bearing deposit (shown in green). The yellow areas represent Quaternary deposits that overlie the Tertiary formations.

Table 2.1. Cumulative area of depth intervals in South River

Depth Interval	Area (sq. km)	% Area	Cumulative %
-2–0 m (islands)	0.69	3.24	3.24
0–2 m	9.10	42.6	45.8
2–4 m	6.09	28.5	74.3
4–6 m	5.03	23.6	97.9
6–8 m	0.35	1.64	99.6

2.3.2 Digital elevation model and landform map

A Digital Elevation Model (DEM) of South River was developed using NOAA-georeferenced sounding data from two hydrographic surveys by the US Coast and Geodetic Survey (Bond & Gossett, 1933; Colbert et al., 1932). The bathymetric data were added to ESRI ArcMap and interpolated for the study site area using kriging.

Contours were added to the DEM at 1 m and 20 cm intervals. The Filled Contours tool (from the Spatial Analyst Supplemental Toolkit) was used to help create polygons at two-meter depth intervals. Concepts described in the Rhode River model (Wessel, 2020) were applied to these ArcMap features to create subaqueous landform polygons in South River (Fig. 2.2). The landforms were delineated based on the proximity of a landform to other subaqueous and subaerial landforms, the water depth where a landform occurs, the three dimensional shape of a landform, and the slope and fetch (length of open water that wind can blow over to generate waves) of the landform.. This was the first step in applying the Rhode River model to South River, and it was completed before any field visits were made to South River. The landforms were named using the terminology used by Wessel (2020), which was developed from a combination of pedological (US Department of Agriculture, 2019) and geological (Neuendorf et al., 2011) terms.

Wave-cut platform (WCP) landforms were delineated in shallow, broad areas abutting the shoreline. Wave-built terrace (WBT) landforms were delineated in deeper areas with steeper slopes (approximately 3%) adjacent to WCPs. Estuarine channel (EC) landforms were delineated in deep, relatively flat (0–1% slope), elongated areas, adjacent to WBTs. In addition to EC landforms, deep estuarine channel (DEC) landforms were delineated in areas with water depths greater than 5.5 meters. These landforms were distinguished because Rhode River has a maximum depth of 5.5 meters, so they represented a novel condition. Nevertheless, they were expected to be similar in soil characteristics to ECs. Submerged Shoal/Saddles (S/S) were delineated in shallow areas surrounded by deeper water. These landforms represent eroded islands and spits. Submerged tidal marshes (STM) were delineated adjacent to emergent marshes. In the tidal creeks, platform, terrace, and channel landforms were delineated using the same rationale as in the main stem. In these narrower tributaries, the platform landforms were called tidal creek platforms (TCP) and the channel landforms were called tidal creek channels (TCC).

Figure 2.2. Draft subaqueous landform map of South River

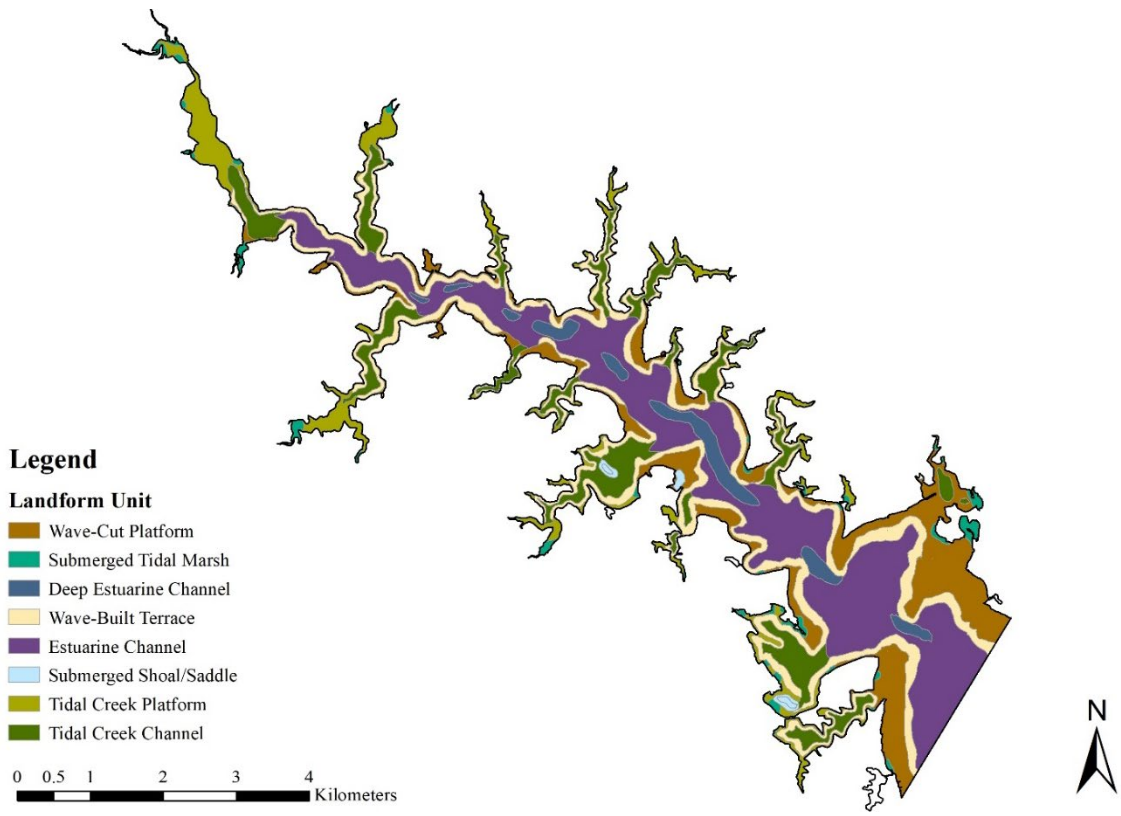


Fig. 2.2. Subaqueous landforms in South River are demarcated in this map which was drafted before any sample collection was conducted. The landforms were delineated based on the methods of the Rhode River study (Wessel, 2020).

2.3.3 Developing the draft soils map

The draft landform map was translated into a draft soils map by correlating soils and landforms from the Rhode River study. Wessel (2020) captured the characteristic soil profiles of each landform in proposed soil series. These soil series served as major components in consociation soil map units that were based upon the delineations of the draft landform map (Fig. 2.3). Since the soil map units of the draft South River soil map were consociations (following the protocol of Wessel (2020)) soil names (series) were correlated to landforms on a one-to-one basis (Table 2.2). In the case of DECs, the Rhode

River study did not provide direct information regarding which soil to map on those landforms, but based on the expected depositional environment, the Sellman series was chosen to be mapped on DECs. The draft map did not include water depth phases for the soil map units.

Table 2.2. South River subaqueous landforms and the soil series from the Rhode River study that were mapped on each landform.

Landform	Soil Series (Major Component in the Soil Map Unit)	Classification
DEC	Sellman	Fine, glauconitic, nonacid, mesic Grossic
TCC	Sellman	Fine, glauconitic, nonacid, mesic Grossic Hydrowassents
EC	Contees Wharf	Fine-silty, glauconitic, nonacid, mesic Grossic Hydrowassents
WBT	Dutchman Point	Glauconitic, mesic Fluventic Psammowassents
STM	Fox Creek	Euic, mesic Sapric Sulfiwassists
S/S	Rhode River	Coarse-loamy, glauconitic, nonacid, mesic Aeric Fluviwassents
TCP	Rhode River	Coarse-loamy, glauconitic, nonacid, mesic Aeric Fluviwassents
WCP	Rhode River	Coarse-loamy, glauconitic, nonacid, mesic Aeric Fluviwassents

The draft soils map generated by applying the Rhode River model to South River represented a hypothesis ready for testing. The representative soils that Wessel (2020) described for each of the landforms served as the predicted soils to which soil observations would be compared.

2.3.4 Field data collection

Sampling was conducted along several transects, which ran shore-to-shore across the river so that the sampling locations covered the gradient from high to low points in the estuary. The sampling locations were centered within each soil map unit that the transect crossed. Six transects of five to twelve sampling points, were distributed throughout the subestuary. Each soil map unit type was sampled in several locations.

A total of 48 sampling points were identified before any field work was conducted. Four supplemental locations were sampled after the initial field work was finished, resulting in a total of 52 observations (Fig. 2.3).

Our goal was to collect soil cores that were 1–2 meters deep at each sampling point, which would be adequate to characterize and classify the soils to support an order 2 soil survey (Soil Science Division Staff, 2017). In some places, we were able to collect cores that were more than two meters long. A Macauley auger was used for sampling soft soil materials, and it does a good job in preserving soil horizons with minimal vertical compaction. It is, however, limited in its use to places where water depth was six meters or less. A vibracorer was used to sample nonfluid materials. Vibracorer samples are well-preserved, but commonly there is some vertical compaction that must be corrected. Its use was limited to places where water depth is five meters or less.

Figure 2.3. Draft South River subaqueous soils map with sampling waypoints

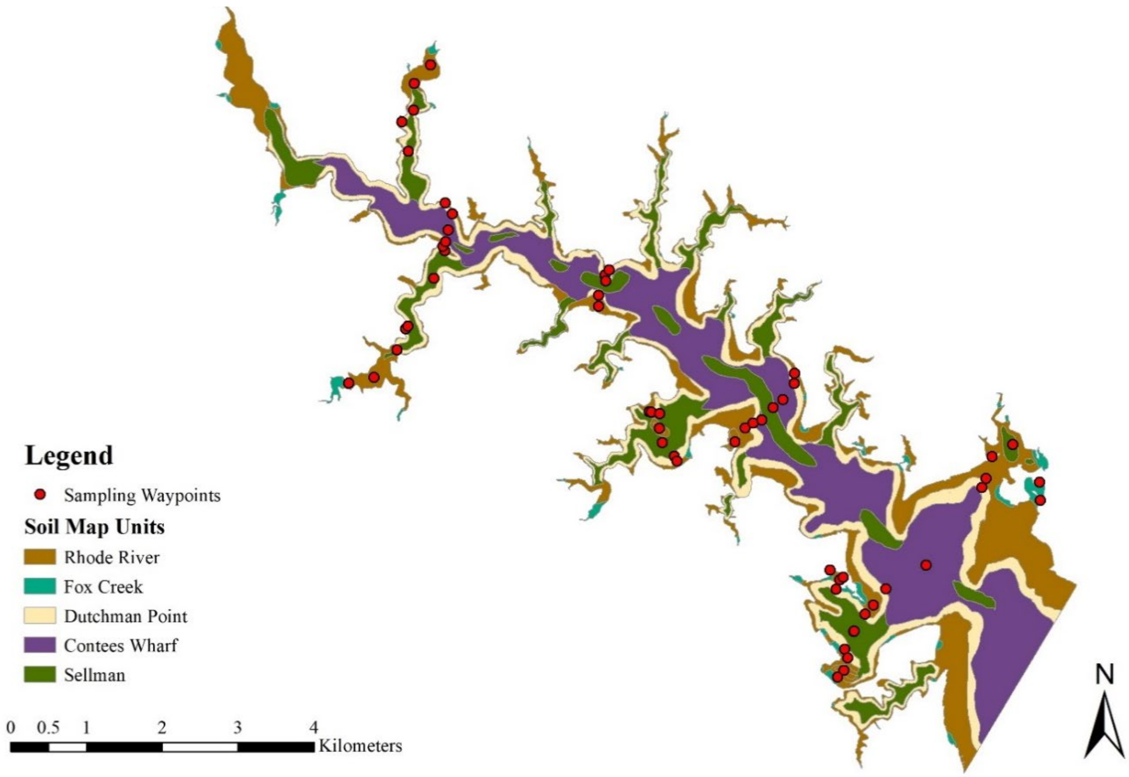


Fig. 2.3. This figure shows the predicted distribution of soils in South River based on the Rhode River soil-landform relationship model. This map was developed before any sampling was conducted. The sampling waypoints are shown in red.

In water too deep for the Macauley auger, a gravity/impact corer was used (Aquatic Research Instruments, Hope, ID), which can collect soil cores up to two meters in length. However, this device does cause some vertical compaction, and extra care must be taken to collect a straight, vertical core.

Soil profiles were described following standard National Cooperative Soil Survey procedures (Schoenenberger et al., 2012) and using description sheet 232. The soil properties described included color, texture, fluidity, odor, fragments, and reaction to hydrogen peroxide; based upon observed properties and depth, soil horizons were named.

Horizons were grouped into the five material types described by Wessel and Rabenhorst (2017): Tertiary material, Holocene sands, Holocene fluid fines, buried A material, and organic soil material. This study did not distinguish between Tertiary material with and without iron oxide concentrations, but rather grouped all Tertiary material together.

Profiles sampled using the Macauley auger were described in the field, and samples from individual horizons were collected in plastic bags, placed in a cooler, and returned to campus, where they were stored frozen at -19°C. Profiles sampled using the vibracorer and gravity corer were described later in the lab. Those cores were stored at 5°C and remained sealed until they were opened and described. After description, samples from each horizon were sealed in plastic bags and stored frozen at -19°C.

2.3.5 Soil analysis

A subset of samples was selected to be analyzed. In some instances, entire soil profiles (cores) were analyzed as pedons representative of a particular landform. In other cases, samples were selected to represent particular material types.

Particle size analysis was conducted using the pipette method (Gee & Or, 2002).

Moist aerobic incubation is a method that identifies hypersulfidic materials via pH measurements taken at two-week intervals over an 8–16-week period (van Breemen, 1982). Approximately 25 grams of soil was mixed with DI water in a plastic container to create a soil paste, and the pH was measured using a calibrated glass electrode. Samples were then allowed to slowly dry over several days, during which time they were occasionally remoistened. Once each week, DI water was added to reconstitute the paste and pH was measured again. This process of wetting and drying with weekly pH measurements continued for 16 weeks.

Selected samples were analyzed to determine the mineralogy for the purposes of correctly classifying the soils at the family level of Soil Taxonomy. Clay fractions were examined using X-ray diffraction techniques and selected sand fractions were counted using optical microscopy following the approach of Balduff (2007).

2.3.6 Classification

Using morphological descriptions and characterization data (including some estimations of properties where needed), all pedons were classified to the family level according to *Keys to Soil Taxonomy*, 12th edition (Soil Survey Staff, 2014a). Although a new wet soil order, Aquasols, which encompasses subaqueous soils, has been proposed, soils were classified according to the currently approved version of *Keys to Soil Taxonomy* and thus they were all included in the Wassents and Wassists suborders.

2.3.7 Model evaluation

The usefulness of the Rhode River model in the South River subestuary was evaluated by comparing the soils observed at each sampling point with the representative soil that was predicted to be at each location based on the Rhode River model.

Three different schemes were used for comparison: 1) the comparison scheme developed by Wessel with a five-point scale (Table 2.3); 2) a modification to the first scheme as proposed by Wessel, also with a five-point scale (Table 2.4); 3) a new scheme using a six-point scale (Table 2.5).

All three schemes shared some characteristics in common – the lowest point in each scheme represented no significant similarities between the expected soil and the observed soil, and the highest point represented a series match between the expected soil and the observed soil.

The term "similar" – used in schemes one and three – is a technical term that refers to soils having properties that are slightly outside the defined taxonomic limits but that would not dramatically impact major land uses (Soil Science Division Staff, 2017). A review of subaqueous soil surveys was conducted to determine the range in characteristics that should be considered similar.

Table 2.3. Comparison scheme 1 – original Rhode River scale used by Wessel (2020)

Class	Criteria
1	Observed soil shares no noteworthy properties with the predicted series and is formed in different parent materials
2	Observed soil is formed in the same parent materials as predicted series (Holocene mineral, Tertiary mineral, organic)
3	Observed soil matches the taxonomic subgroup of the predicted series
4	Observed soil is similar to the predicted series (i.e., shares most interpretive properties)
5	Observed soil matches predicted soil series

Table 2.4. Comparison scheme 2 – revised Rhode River scale proposed by Wessel (2020)	
Class	Criteria
1	Observed soil possesses none of the diagnostic materials or horizons of the predicted series within 2 m of the soil surface. Unexpected diagnostic horizons or materials are present within 2 m of the soil surface (Cambic Horizon and Ochric Epipedon exempted).
2	One or more predicted diagnostic horizons or materials of the predicted series are absent from within 2 m of the soil surface AND unexpected diagnostic horizons or materials are present within 2 m of the soil surface (Cambic Horizon and Ochric Epipedon exempted).
3	One or more predicted diagnostic horizons or materials of the predicted series are absent from within 2 m of the soil surface OR unexpected diagnostic horizons or materials are present within 2 m of the soil surface (Cambic Horizon and Ochric Epipedon exempted).
4	All diagnostic horizons and/or materials of the predicted series are present within 2 m of the soil surface. No unexpected diagnostic horizons or materials are present within 2 m of the soil surface.
5	Observed soil matches the predicted series.

Table 2.5. Comparison scheme 3 – South River scale (developed for this study)	
Class	Criteria
1	Observed soil has no meaningful similarities to the expected soil
Material type questions: - Within 100 cm, are there ≥10 cm nonfluid materials? - Within 100 cm, are there ≥10 cm slightly fluid to very fluid materials? - Within 100 cm, is there tertiary material (paleosol)?	
2	Observed soil has one out of three material type questions correct
3	Observed soil has two out of three material type questions correct
4	Observed soil has all three material type questions correct
5	Observed soil is similar to expected soil (i.e., shares most interpretive properties)
6	Observed soil matches the predicted series

The initial South River soil map was evaluated by comparing the soils observed at each sampling point to the soils predicted in each location based on the Rhode River model. This comparison was conducted once for each of the comparison schemes. There were seven possible soil series from the Rhode River study that could be mapped in South River, so in order to reduce investigator bias in the comparison, each observed soil was compared to all seven possible soils before identifying the expected soil for the observation's sampling location. Values 1–5 (or 1–6, in the case of comparison scheme three) were assigned to each of the 52 observations. Higher values indicated a better fit between the observed soil and the soil from the Rhode River study to which the observation was being compared.

This process yielded comparison matrices for the three schemes that tabulated the scores for each South River observation and each possible series from the Rhode River study (see Appendix E). Then, the expected soil for each sampling point was identified based on the Rhode River model. The comparison scores for the expected soil were isolated and aggregated to generate an observed map score for the draft soil map.

The three comparison schemes presented three sets of criteria for evaluating the Rhode River model, and resulted in three comparison matrices, which served as the quantitative basis for the evaluation. In the statistical analysis of the comparison scores, the datasets of the three schemes all went through the same analyses separately.

Following the method of Wessel (2020), we conducted bootstrapping analysis to test the significance of the observed map score and evaluate whether using the Rhode River model positively contributed to the mapping effort.

We tested the following null hypothesis: H_0: the observed map score, generated from the distribution of soils in South River predicted by the Rhode River model, is not significantly different than a map score generated by comparing the observed soils to one of the seven possible series, selected randomly.

Using the comparison scores that had been assigned to each observed soil for every possible expected soil, the 52 observations were resampled. Instead of comparing each observed soil to the soil expected for its sampling location based on the Rhode River model, each observed soil was compared with one of the seven possible expected soils, selected randomly. The random selection process was weighted so that the series from the Rhode River study that were more extensive in the South River draft soil map were more likely to be selected as the point of comparison in the resampling (i.e. the proportional weighting of the random sampling was equal to the proportion of the seven different soils observed in the original sampling). The scores achieved for each of these resampled comparisons were taken from the comparison matrices. The values for all 52 observations were summed to generate an aggregated map score, this time based on the proportionate random assignment of soils for comparison (note that this would be in contrast to the original observed map score, which was based on the Rhode River model.) This procedure was iterated 10,000 times to generate 10,000 separate datasets and 10,000 random aggregated map scores. Following the method of Wessel (2020), the 95th percentile of the random map scores was chosen as the significance threshold. This threshold and the observed map score were used to test the null hypothesis.

2.4 Results and Discussion

2.4.1 Soil observations in South River

On the wave-cut platform landforms, the representative soil was one with a mantle (16–74 cm thick) of Holocene sandy material overlying a truncated paleosol (tertiary material), containing hypersulfidic materials. Representative soils on the submerged shoal/saddle landform also were composed of Holocene sands over a truncated paleosol, but the textures were sandier than on the wave-cut platform. By contrast, soils of the tidal creek platform landforms generally had a mantle of Holocene fluid fine material overlying the Tertiary material, and often included a buried A horizon. The fine texture of the mantle was attributed to the lower depositional energy within the tidal creeks. On the submerged tidal marsh landforms, the representative soil contained a thin mantle of Holocene sand and an organic horizon overlying a relatively intact submerged upland marsh soil that exhibited relic features of subaerial pedogenesis, including eluviation, illuvial clay accumulation, and iron-oxide concentrations. On the wave-built terrace landforms, soils generally comprised stratified layers of Holocene sands, implying numerous depositional events under varying conditions. Because the material type was largely the same, these sequential deposits were not considered to represent lithological discontinuities. The estuarine channel, deep estuarine channel, and tidal creek channel landforms all had similar representative soils. As expected, the estuarine channel and deep estuarine channel had deep profiles (3+ meters) of black, sulfide-enriched Holocene fluid fine material. Based on their similarity, the deep estuarine channel landform was integrated into the estuarine channel landform in the revised landform map. In Glebe Bay and Selby Bay, estuarine channel landforms were renamed as mainland coves because of the round, open morphology of the subestuary in those places. The representative soils there were similar to those of the estuarine channel soils. The soils in tidal creek channels were also similar but typically contained a buried A horizon.

2.4.2 Model Testing

The bootstrapping approach generated 10,000 random map scores, the 95th percentile of which was used as a significance threshold against which to test the null hypothesis. For all three comparison schemes, the observed map score exceeded the significance threshold of the distribution of random map scores (Figure 2.4). Comparisons using schemes one and three demonstrated that the observed map score even exceeded the 99^{th} percentile random map score. Therefore, the null hypothesis was rejected as the observed map score is significantly better than the scores from randomly generated mapping.

The bootstrapping analysis demonstrated that the Rhode River model provided significant useful guidance to map soils according to landform in South River, and that the model is an effective approach for subaqueous soil survey efforts in western shore subestuaries of Chesapeake Bay. However, it was not able to illuminate the specific strengths or weakness of using the Rhode River model to predict soil distributions. By looking more closely at the comparison scores, we were able to identify trends in what the model successfully predicted and what it overlooked.

In all three comparison schemes (Tables 2.3, 2.4, and 2.5), a higher score indicated greater similarity between the two soils being compared. However, each scheme used slightly different criteria for the comparison. Scheme 1 (the original Rhode River scale used by Wessel in his model testing study in West River), focused on taxonomy and land-use interpretations. The scheme was flawed because some classes were too broad, grouping dissimilar soils, and others were too narrow, such that they were not used at all.

Figure 2.4. Random map scores generated from resampling

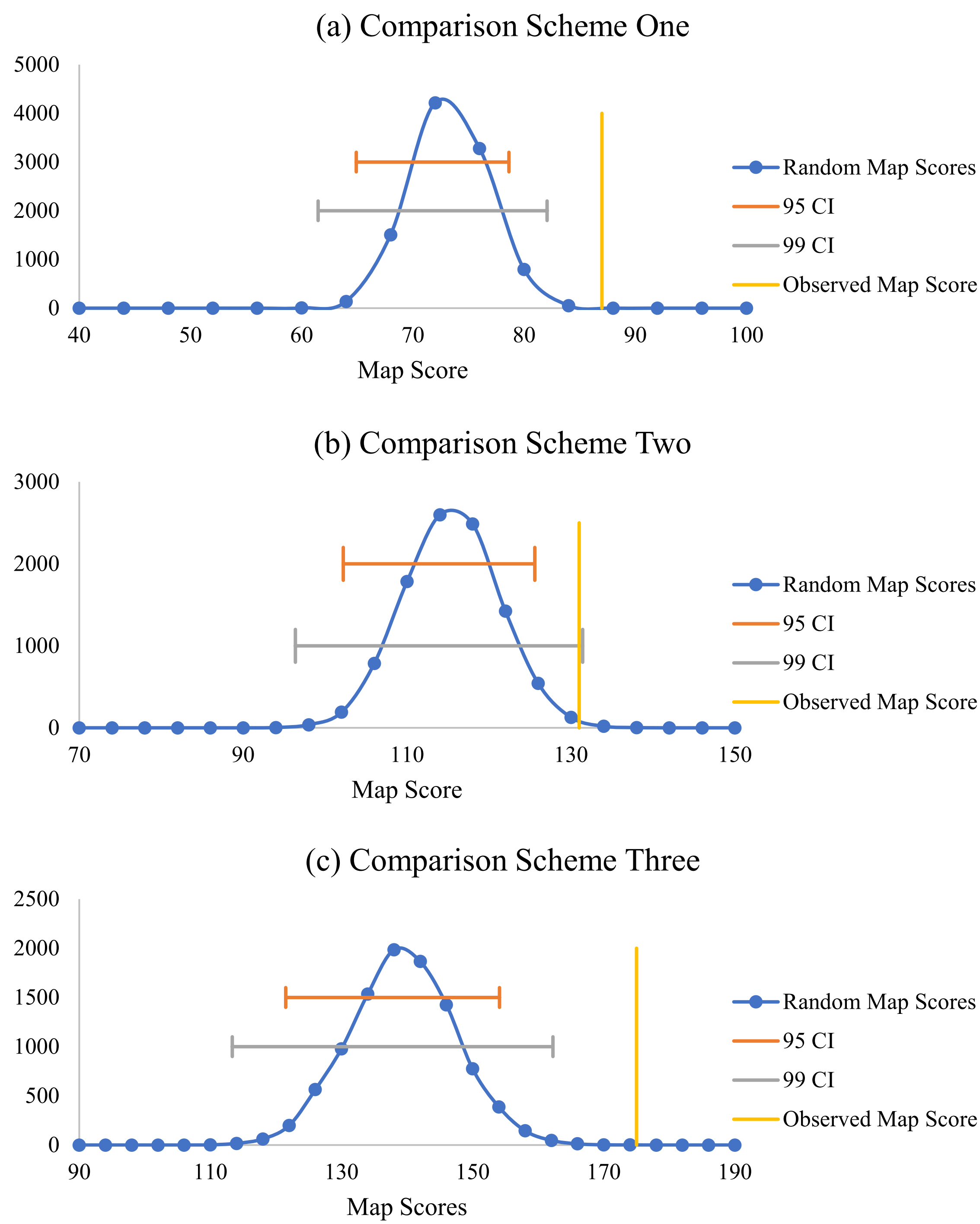


Fig. 2.4. These figures show the distribution of random map scores generated in the bootstrapping analysis. The observed map scores exceeded the 95th percentile of the random map scores, justifying the conclusion that the Rhode River model provides significant useful information about the distribution of soils in Chesapeake Bay.

The second scheme was proposed by Wessel as a revision to the first. It focused on the presence or absence of diagnostic horizons and features rather than taxonomy or interpretations. The third scheme, designed for the present study, was focused on presence or absence of soil material types. The scheme included three questions about material types, and "correct" answers to the questions resulted in a higher comparison score. To "correctly" answer the questions, the observed soil needed to exhibit the presence or absence of a material type the same way as the predicted soil to which it was being compared. Since the Rhode River model focused on material types, we believed a comparison scheme with the same focus would be an apt evaluation tool.

The comparison schemes were examined by generating histograms to visualize the frequency of the comparison scores (Fig. 2.5). They demonstrated that none of the observed soils matched the predicted series for its sampling location (score = 6 in scheme three), and very few observations were similar to the predicted series (score = 5 in scheme three). The modal score using comparison scheme one was 2, which was defined as, "the observed soil matches the parent materials of the predicted soil." The modal score using comparison scheme two was also 2, which in that scale was defined as "the observed soil lacks some diagnostic feature(s) of the predicted soil and contains diagnostic features that are not part of the predicted soil". The modal score using comparison scheme three was 4, meaning that the observed soil exhibited the presence or absence of the three main soil material types as expected based on the predicted soil.

Figure 2.5. Distribution of comparison scores

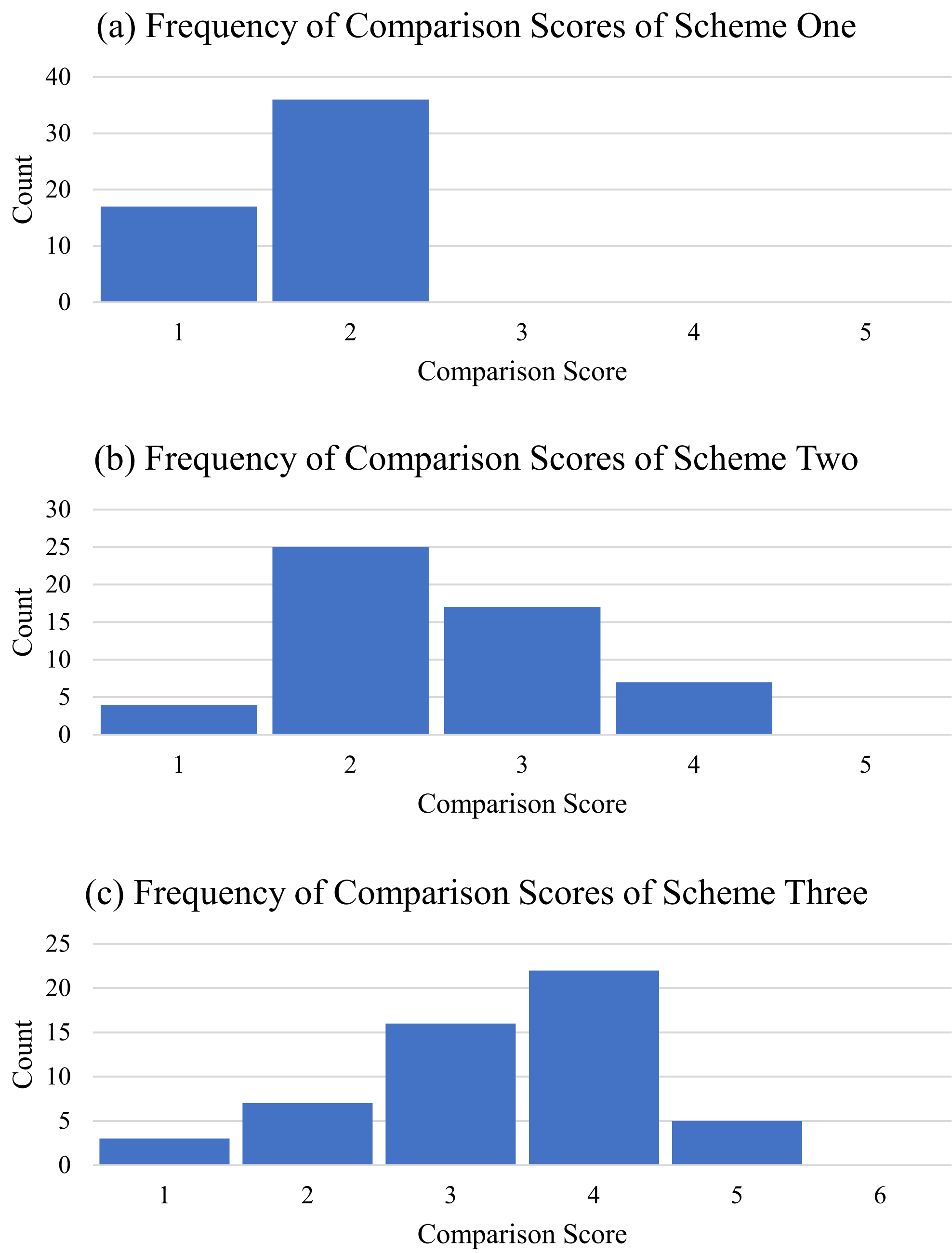


Fig. 2.5. These figures show the frequency of comparison scores in all three comparison schemes. In schemes one and two, the modal score was 2 (a, b). In scheme three, the modal score was 4 (c). The modal scores demonstrate that the Rhode River model was able to predict the distribution of soil material types. It was not able to predict the distribution of soil series because it failed to account for some diagnostic features, such as hypersulfidic materials.

The Rhode River model's successful prediction of the distribution of soil material types is an important result because it helps infer soil properties and interpretations in the first approximation. Without sampling the study site, we can already predict favorable locations for oyster leases; submerged aquatic vegetation; and docks, moorings, and marinas.

Though the Rhode River model successfully predicted the distribution of soil material types in South River, it was less successful in predicting other diagnostic features. In particular, the model did not predict the abundance and distribution of hypersulfidic materials. The soils observed in the Rhode River study typically did not contain hypersulfidic materials, so they were not addressed in the model. By contrast, the South River soils typically were hypersulfidic. Two-thirds of South River horizon samples that were tested were hypersulfidic materials based on the observed drop in pH, including 12 out of 22 (55%) Holocene sand samples and 58 out of 76 (76%) Holocene fluid fine samples. These material types are always surficial, so they are inundated by sulfate-rich estuarine waters, which is the first step in sulfide mineral accumulation (Fanning and Fanning, 1989). Furthermore, they are relatively high in organic carbon, which helps drives sulfidization. Tertiary materials sometimes contained hypersulfidic materials (8 out of 23 samples, or 35%). Hypersulfidic materials may occur less frequently in Tertiary materials for numerous reasons. First, sulfidization could be slow in these materials. Wessel (2020) observed that organic carbon in Tertiary materials in Rhode River ranged 0.1–0.4%, which may not be sufficient to drive sulfate reduction. It is likely that any sulfides present in Tertiary materials formed not by sulfate reduction *in situ*, but rather by the reaction of iron oxides and H_2S gas that diffused from overlying horizons (Wessel, 2020), which could result in lower sulfide content in these materials. Second, even if sulfides accumulate in these materials, the high clay content of Tertiary materials in South River imparts buffering capacity that neutralizes acidity that results from sulfuricization.

Hypersulfidic materials were most abundant on landforms in South River dominated by Holocene sands or Holocene fluid fines (wave-built terraces, estuarine channels, mainland coves, tidal creek channels, and tidal creek platforms). Hypersulfidic materials were less common on wave-cut platforms because of the presence of Tertiary material in the upper 100 centimeters of the soil profile.

The relative abundance of hypersulfidic materials in South River could be due to a variety of factors. Rhode River soils might be higher in carbonates, which can neutralize acidity generated during moist aerobic incubations. Alternatively, South River soils might be higher in organic carbon, which is required for sulfate reduction, and which could lead to accumulation of greater quantities of Fe sulfide minerals.

2.4.3 Proposed new soil series

The statistical comparison of the predicted soils and the observed soils demonstrated that many soils in South River did not fit the series proposed in the Rhode River study (Wessel, 2020). Therefore, new soil series were developed to accommodate the soils. In most cases, the new series were similar in concept to those from the Rhode River study, the main difference being that the new soils included hypersulfidic materials. The new proposed series were, in the simplest terms, “hypersulfidic versions” of the series proposed by Wessel in Rhode River. The classification and major characteristics of the proposed series are in Table 2.6. The data used to develop the proposed series can be found in Appendices A–D, and full draft descriptions of the proposed series can be found in Appendix F.

Table 2.6. New proposed soil series for the South River study.

Proposed Series	Major characteristics	Classification	Rhode River Series Analogs
South River	Weathered Tertiary material in upper 100 cm	Coarse-loamy, glauconitic, nonacid, mesic Aeric Sulfiwassents	Rhode River
Duval Creek	Thick, stratified Holocene sands	Mixed, mesic Sulfic Psammowassents	Dutchman Point
Cornballer	Deep Holocene fluid fines	Fine-loamy, mixed, subactive, nonacid, mesic Fluventic Sulfiwassents	Contees Wharf
Long Point	Organic horizon over Tertiary material (less truncation)	Fine-loamy, mixed, subactive, nonacid, mesic Typic Sulfiwassents	Fox Creek
Glebe Bay	Buried shell layer and Tertiary material in upper 100 cm	Sandy, mixed, subactive, nonacid, mesic Haplic Sulfiwassents	-
Broad Creek	Holocene fluid fines with buried A horizon	Fine-loamy, mixed, subactive, mixed, mesic Fluventic Sulfiwassents	Sellman
Overboard	Holocene fluid fines with buried A horizon and deep lithological discontinuity	Fine-loamy, mixed, subactive, nonacid, mesic Fluventic Sulfiwassents	-

Table 2.6. Major characteristics and classification of proposed series. All the proposed series contained hypersulfidic materials within the upper 50 or 100 cm. The Glebe Bay and Overboard series did not have close non-hypersulfidic analogs from the Rhode River study. The Glebe Bay series was proposed for soils on Submerged Shoal/Saddle landforms, which were mapped as Rhode River soils in the draft. The Overboard series was proposed for soils on Tidal Creek Platform landforms, which were mapped as Sellman soils in the draft.

The **South River** series encapsulates the representative soil of the wave-cut platform landforms; it includes 15 to 40 cm of Holocene sandy material overlying Tertiary material. These soils contain hypersulfidic materials within the upper 50 centimeters of the soil profile. The layer of Holocene sands can sometimes extend to 75 cm deep and can include a buried shell layer. Regardless, the pedon's control section (0–100 cm) is dominated by Tertiary material, which has sufficient glauconite content for the soil to qualify for the glauconitic mineralogical family class. The series is the hypersulfidic analog to the Rhode River series.

The **Duvall Creek** series captures the representative soil of the wave-built terrace landforms. Duvall Creek soils are composed of stratified deposits of Holocene sandy material. In Rhode River, the Dutchman Point series (Fluventic Psammowassents without hypersulfidic materials in the upper 100 centimeters) was developed to capture soils composed of Holocene sandy material. By contrast, Duvall Creek soils contain hypersulfidic materials within the upper 50 centimeters, and typically include a buried shell layer (up to 70% shell fragments by volume).

The **Cornballer** series represents the representative soil of the estuarine channel and mainland cove landforms. Cornballer soils (composed of deep Holocene fluid fine materials) are black, very fluid, and contain hypersulfidic materials within the upper 50 centimeters. The series is the hypersulfidic analog to the Contees Wharf series.

The **Long Point** series captures the representative soil of the submerged tidal marsh landforms. Long Point soils comprise a mantle of Holocene sands above an organic horizon overlying a relatively intact paleosol (Tertiary material); they contain hypersulfidic materials in the upper 50 centimeters. In Rhode River, submerged tidal marsh landforms were mapped as Fox Creek soils, which are Histosols (Euic, mesic Sapric Sulfiwassists).

The **Glebe Bay** series captures the representative soil of the submerged shoal/saddle landforms, which includes a mantle of Holocene sands overlying a truncated paleosol and contains hypersulfidic materials within the upper 50 centimeters.

The **Broad Creek** series captures the representative soil of tidal creek channel landforms, which is formed in deep Holocene fluid fine material. Broad Creek soils contain a buried A horizon and hypersulfidic materials in the upper 50 centimeters and are analogous to the Sellman series.

The **Overboard** series represents the representative soil of tidal creek platform landforms. Overboard soils are more fine-textured and fluid than those in the main channel of the subestuary (Cornballer series) and are formed in 150 to 200 cm of Holocene fluid fine material overlying Tertiary material. They contain hypersulfidic materials within the upper 50 cm and include a buried A horizon and a lithological discontinuity (pre-Holocene contact). The series was named for the instance that I fell overboard while sampling at the series' type location. This never occurred during the Rhode River Study (B. Wessel, *personal communication*, August 2019), and a review of relevant literature revealed that it did not occur in other subaqueous soil surveys in Maryland (Demas, 1999; Balduff, 2007), indicating that my hands-on approach to field work was a novel contribution to subaqueous soil survey in the Maryland coastal plain region.

Broad Creek, Cornballer, and Overboard are competing series (being in the same taxonomic family) that are all formed in deep Holocene fluid fine material and include hypersulfidic materials. Broad Creek differs from Cornballer because it contains a buried A horizon. Overboard is unique because it contains a buried A horizon (which differentiates it from Cornballer) and also a lithological discontinuity over tertiary materials (which differentiates it from Broad Creek).

2.4.4 Revised soil map

Using the information gained from the South River study, the original draft soils map of South River was revised to reflect most current knowledge (Fig. 2.6). Some landforms were re-delineated based on field observations: the wave-cut platform was extended in Glebe Bay; deep estuarine channel polygons were integrated into the estuarine channel landform. Two areas (Selby Bay and Glebe Bay) mapped as tidal creek channels in the draft map were renamed as mainland cove landforms because of their open, round morphology. This did not change the soil map unit designation for these areas (Cornballer).

Figure 2.6. Revised subaqueous soils map of South River

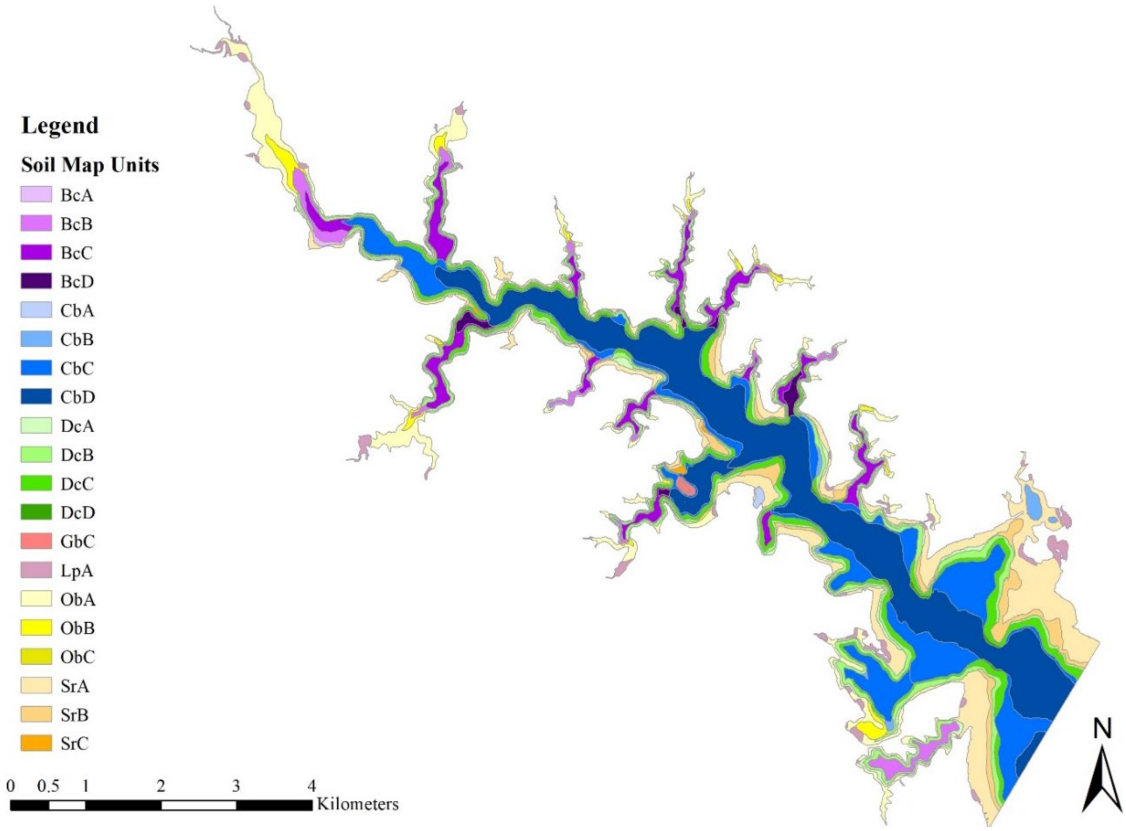


Fig. 2.6. This figure depicts the revised map of subaqueous soils in South River, Md. The legend uses abbreviations for the new proposed soil series. Bc = Broad Creek; Cb = Cornballer; Dc = Duvall Creek; Gb = Glebe Bay; Lp = Long Point; Ob = Overboard; Sr = South River. The third letter in each legend entry represents the depth phase of the soil map unit. A = 0–1 m; B = 1–2 m; C = 2–4 m; D = 4+ m.

2.5 Conclusions

Prior to Wessel's study of Rhode River, the soil-landscape paradigm had been applied to subaqueous settings only to describe landforms and soils. This study corroborates the Rhode River study, indicating that pedological principles can be beneficially applied in these settings, and the predictive power of the soil-landscape paradigm can and should be employed. The Rhode River soil-landform relationship model provided much useful guidance in predicting the distribution of soils in South

River. The distribution of soil material types in South River (primarily Holocene sands, Holocene fluid fines, and Tertiary material) aligned with the Rhode River model. The shallow platforms that ring the subestuary were generally truncated paleosols overlain by a mantle of Holocene sands. The sandy terraces were composed of stratified Holocene sand deposits and the deep, elongated channels were composed of Holocene fluid fines. The tidal creeks were long, narrow, low energy areas where Holocene fluid fines dominated the soil profiles. The tidal creeks may have higher organic carbon than the main stem because they have a large shoreline relative to their area and therefore could receive more detrital carbon. Submerged tidal marshes had organic horizons overlying tertiary material but did not qualify as Histosols. Hypersulfidic materials were present throughout South River, but were primarily found on wave-built terraces, estuarine channels, tidal creek channels, and tidal creek platforms. Additional work on the presence of hypersulfidic materials is needed to better understand the landscape characteristics that can be used to predict the distribution of hypersulfidic materials.

This model, with revisions to accommodate a greater preponderance of soils with hypersulfidic materials, is expected to be applicable to other western shore subestuaries of Chesapeake Bay. Modifications may need to be made for geology and water column attributes, which are likely to change in the upper section of Chesapeake Bay, where freshwater inputs are more significant. The six-point comparison scheme and bootstrapping analysis employed in this study can be used to evaluate future subaqueous soil surveys.

The ability to predict the distribution of soil material types and hypersulfidic materials indicates the soil-landscape paradigm is applicable in subaqueous settings, facilitates efficient mapping, and allows surveyors to estimate soil characteristics and suitability for aquaculture, SAV restoration, and dock or marina construction.

Chapter 3: Methodology and Classification of Subaqueous Soil Porewater Halinity

3.1 Abstract

Halinity, the ocean-derived salt content of coastal waters and soils, is an important characteristic of soils in the coastal zone, including subaqueous soils. This study proposes standards for use in determining and describing subaqueous soil halinity, with the goal of helping soil scientists move towards harmonization with the protocols of other scientific disciplines with a longer history of coastal zone research. First, we propose a system for classifying soil halinity that is based on the Venice System and includes modifications that incorporate recent research on the threshold between fresh and saltwater subaqueous soils. Second, we propose a standard methodology to determine soil halinity that is simple and reliable. We successfully tested the method on the subaqueous soils of South River, a western subestuary of Chesapeake Bay. For the method to be useful, care must be taken to prevent sulfide oxidation and changes in soil moisture content during samples storage and preparation.

3.2 Introduction

3.2.1 Halinity

Halinity is the ocean-derived salt content of coastal waters and soils. This should be understood as distinct from salinity, which refers to the salt content of arid, inland soils which can have a variety of sources. Halinity is an important characteristic of soils in the coastal zone. It influences soil chemistry of subaqueous soils and impacts the survival of both emergent wetland vegetation and submerged aquatic vegetation (Flowers & Colmer, 2015; He et al., 2017). High halinity can impact biogeochemical processes (such as sulfate reduction), become toxic to sensitive aquatic species, and have deleterious human health effects (Kaushal et al., 2005).

3.2.2 Measuring halinity

Describing the halinity of a site is challenging in brackish systems such as Chesapeake Bay because it is dynamic and unstable. Sea water can be diluted by freshwater inputs. Tides and currents move masses of water within the estuary, exposing the benthic environment to different halinity conditions. Soils in the intertidal area can be subaerially exposed and halinity can be concentrated by evaporation, or diluted by precipitation (den Hartog, 1974). Furthermore, some studies investigate water column halinity, while others investigate soil porewater halinity. Water column halinity can be higher or lower than that of the porewater depending on tidal inundation, evapotranspiration, precipitation, and freshwater input (Cao et al., 2012; Hughes et al., 2012). All these factors make it challenging to collect representative samples and determine the halinity of a given site.

Halinity is commonly reported in parts per thousand or “practical halinity” (which relates directly to parts per thousand, although it is a unitless descriptor defined as a ratio – the measured value divided by a reference value within the meter). However, halinity is commonly determined by measuring electrical conductivity (EC). Dissolved ions conduct electricity, so the EC is a direct effect of the type and concentration of dissolved ions present (CWT, 2004). Electrical conductivity, which typically is reported in units of dS/m or μS/cm, can be converted to halinity in parts per thousand using a conversion factor, which can change depending on the ionic composition and ionic strength of the sample. Generally, 1 dS/m = 0.64 ppt is used as a rule of thumb for EC values between 0.1 dS/m and 5 dS/m; 1 dS/m = 0.8 ppt is used for EC values greater than 5 dS/m (Hanson et al., 2006).

For water samples, EC is measured simply by inserting an electrical conductivity probe into the sample. For soil porewater samples, the porewater must be extracted from the soil to be measured. This can be done several ways. Historically, a common method was vacuum extraction of a saturated soil paste, where a vacuum apparatus was used to extract water from a soil sample to which sufficient water had been added to form a "paste", and then the extract was measured with a conductivity probe. This method was commonly used for saline soils in arid or semi-arid environments, but it does not work well for subaqueous soils. Another common method is to measure the conductivity of the supernatant of a 1:1 soil/water mixture (Soil Survey Staff, 2014b). The most widely used method for subaqueous soils is the 1:5 dilution by volume method, where one part (by volume) of a fresh (or refrigerated) subaqueous soil sample is mixed with five parts (by volume) distilled water and allowed to equilibrate before the EC of the supernatant is measured (Soil Survey Staff, 2014b). This method (typically referred to as the $EC_{1:5}$ method) is popular because it is simple and quick, so it can be performed in the field, and because it provides ample solution for measurement. However, the method does not produce data that reflects the real condition of the soil because the soil sample (and its porewater) is diluted with distilled water. Although the *bulk* dilution is consistent (1:5), the dilution of the porewater varies depending on the soil's bulk density and moisture content. If a sample's bulk density and moisture content are known, they can be used to calculate the dilution of the porewater and thereby determine the porewater EC. Often, soil scientists eschew this process and simply conduct the $EC_{1:5}$ method and report in terms of $EC_{1:5}$. Nevertheless, it is useful to convert from $EC_{1:5}$ to porewater EC because the latter reflects the real condition of the soil. Furthermore, porewater EC can be converted to porewater halinity, which is the parameter used by other scientific disciplines. In order to communicate soils information and foster interdisciplinary work in the coastal zone, it is important to use a common language.

3.2.3 Halinity classification

After halinity is measured, classification provides another challenge. Gradation from fresh water to marine water is gradual and continuous, so class boundaries cannot avoid some degree of artificiality (Cowardin et al., 1979). Many foundational classification systems were developed in Northern Europe in the early 20th century. These systems were based on the halinity tolerance of benthic ecological communities (e.g., Redeke, 1922) or the distribution of a single organism (e.g., Valikangas, 1926). These early studies specified the criteria used to develop their classification systems and remarked that the halinity thresholds may require revision in regions with different hydrological or ecological characteristics (den Hartog, 1974). Unfortunately, their disclaimers did not prevent confusion, so the international Symposium for the Classification of Brackish Waters was held in 1958 to create a unified classification system from the various systems in use in Europe at the time (Venice System, 1959; see Table 3.1).

Table 3.1. Early European systems of halinity classification							
Source	Study Location	Boundary Criteria	Units	Extraction method	No. Classes	Major Boundaries	Citation
Redeke (1922)	Netherlands estuary	Benthic community	chlorinity (ppt Cl-)	water sample (no extraction needed)	5	Fresh ≤ 0.1 ppt Cl- Three brackish classes Marine ≥ 17 ppt Cl-	Redeke (1922)
Valikangas (1933)	Gulf of Finland	Plankton	chlorinity (ppt Cl-)	water sample (no extraction needed)	5	Fresh ≤ 0.3 ppt Cl- Three brackish classes Marine ≥ 16.5 ppt Cl-	Valikangas (1933)
Remane (1940)	Baltic Sea	Brackish Fauna	ppt	water sample (no extraction needed)	5	Fresh ≤ 3 ppt Marine ≥ 16.5 ppt	Remane (1940)
Brattstrom (1941)	Skagerrak and Baltic Sea	echinoderms	ppt	water sample (no extraction needed)	-	Marine > 32 ppt	Dahl (1956)
Ekman (1953)	North Sea	Unspecified	ppt	water sample (no extraction needed)	7	Fresh ≤ 0.5 ppt Three brackish classes Three marine classes	Dahl (1956)
Dahl (1956)	Review of existing systems	Brackish Fauna	ppt	water sample (no extraction needed)	5	Brackish water 5–25 ppt Marine ≥ 30 ppt	Dahl (1956)
Venice (1959)	Review of existing systems	Unspecified	ppt	water sample (no extraction needed)	8	fresh ≤ 0.5 ppt Four brackish classes Marine 30–40 ppt	Venice (1959)

Table 3.1. The early European systems of classification focused on water column halinity. They varied in their designation of fresh and marine water boundaries, and in the number of subdivisions for brackish water.

The resulting "Venice System" was a revision of the early European systems, but it did not make explicit the criteria used to define its classes. The system's stated goal was to create classes that encompassed the halinity range of all marine systems. It included classes with higher and lower halinity values than the European systems in order to capture conditions found in Southern Europe, South Africa, and other areas (Table 3.2). It also introduced the terminology of "mixo-" classes, which were created for use in brackish waters. The authors considered "brackish" to be an ambiguous term, so "mixohaline" was proposed as an alternative. "Mixo-" prefixes were also proposed for the intermediate halinity classes when they were identified in brackish settings.

Table 3.2. Venice system of brackish water classification	
Class Name	Halinity (parts per thousand)
Hyperhaline	> ±40
Euhaline	±40–±30
Mixohaline	(±40) ±30–±0.5
Mixoeuhaline	> ±30 but < adjacent euhaline sea
(Mixo-) polyhaline	±30–±18
(Mixo-) mesohaline	±18–±5
(Mixo-) oligohaline	±5–±0.5
Limnetic (fresh water)	< ±0.5

The authors of the Venice System emphasized that the variability of brackish environments cannot be constrained by any classification, remarking that classification based on mean halinity is not sufficient to describe an ecosystem, and additional data about halinity range and ecological characteristics will always be necessary. They included the "±" symbol with all the threshold values to indicate that the values defining the classes are approximate and suggested the idea of subdivisions within the proposed classes if ecological observations warranted finer distinctions (Venice System, 1959).

3.2.4 Legacy of the Venice System

The Venice System has proven to be influential in subsequent research and classification efforts (Table 3.3). In the United States, halinity classification was incorporated into wetland classification systems in the 1970s because of halinity's effect on the community composition of wetland vegetation and animals (Cowardin et al., 1979). The Venice System was adopted by the US Fish and Wildlife Service in its wetland classification system, which was titled *Classification of Wetlands and Deepwater Habitats of the United States*, but is often referred to as the Cowardin System, perhaps as an homage to the convention to refer to the old European systems by their primary authors. The Cowardin System used the Venice System classes as modifier classes for coastal water halinity and inland water salinity. A drawback of this double use of the Venice System is that it de-emphasized the distinction between halinity and salinity (Theve, 2014). A modified version of the Venice System was also adopted by the US Coastal and Marine Ecological Classification Standard (CMECS) (FGDC, 2012). The main modification was the subdivision of the polyhaline class into lower polyhaline (18 to <25 ppt) and upper polyhaline (25 to <30 ppt).

3.2.5 Drawbacks of the Venice System and impetus for regional systems

The Cowardin System and CMECS have extended the influence of the Venice System in the United States, but the limitations of the system, which were broached by its authors in 1958, mean its classes are too broad to meaningfully describe soil map units or ecological sites without additional data. The authors of the Venice System sought to encompass the range from fresh to marine water while avoiding a proliferation of terms, so the system's classes group halinity values that could give rise to disparate vegetative communities depending on climate or topography. In recent years, researchers have conducted regional studies focused on soil porewater halinity, rather than water column halinity, with the goal of generating more specific halinity classes that align with vegetative communities and provide more information in a single term as part of ecological site descriptions and soil surveys (Hutchinson, 1988; Taupp & Wetzel, 2014; Theve, 2014; see Table 3.3).

Table 3.3. Halinity classifications systems in the United States							
Source	Study Location	Boundary Criteria	Units	Extraction Method	No. Classes	Major Boundaries	Citation
USFWS (Cowardin system)	For use in US wetlands	Based on Venice System	ppt	water sample (no extraction needed)	8	Fresh ≤ 0.5 ppt Marine 30–40 ppt	Cowardin (1979)
Hutchinson (1988)	Washington state tidal wetlands	wetland vegetation	ppt	soil paste extraction, water samples	6	Very sensitive ≤ 0.5 ppt Very tolerant > 20 ppt	Hutchinson (1988)
NRCS-KSSL (1993)	USA	Regularly distributed classes	EC (mmhos/cm or dS/m)	saturated soil paste extract	5	Non saline 0–2 dS/m Very slightly saline 2–4 dS/m Slightly saline 4–8 dS/m Moderately saline 8–16 dS/m Strongly saline ≥16	Soil Survey Division Staff (2017)
CMECS	For use in US wetlands	Based on Venice System	practical salinity	water sample (no extraction needed)	6	No fresh class Oligohaline <5 Marine 30–40	FGDC (2012)
Theve (2014)	Connecticut tidal marshes	wetland vegetation	dS/m (EC1:5)	EC 1:5 dilution by volume	4	Tidal fresh marsh 0.41-0.87 dS/m Low salt marsh 3.01-3.97 dS/m	Theve (2014)
Stemmans (2018)	Louisiana coastal soils	wetland vegetation	dS/m (EC1:5)	EC 1:5 dilution by volume	4	Fresh ≤ 0.6 dS/m Intermediate ≤ 2 dS/m Brackish ≤ 8 dS/m Saline > 8 dS/m	Payne (2018); R. Tunstead, *personal communication*, March 2020

Table 3.3. Several nationwide halinity classifications systems exist in the US. Recent regional studies use different methods of halinity measurement and different criteria for class boundaries.

A drawback of linking halinity classes to regional vegetative communities is that the classes are not applicable on a broad scale. Halinity does influence the survival and health of plants in wetland and subaqueous settings, but other factors, like temperature regime, precipitation, and tidal range, also exert control. As a result, classes proposed for Connecticut tidal marshes (Theve, 2014) do not align with those proposed for

Washington state wetlands (Hutchinson, 1988) or Louisiana coastal soils (R. Tunstead, *personal communication*, March 2020).

The objectives of this study were:

1. To assess existing halinity classification systems and propose a synthesized, broadly applicable system for coastal zone soils

2. To develop, test, and recommend a feasible and meaningful method of measuring EC in subaqueous soil porewater

3. To assess the soil porewater halinity of the subaqueous soils of South River

3.3 Methods

3.3.1 Approach to formulating halinity classes

A review of halinity classification systems and other relevant literature was conducted and the criteria and terminology of existing systems were compared. The new classes that were formulated prioritized broad applicability and familiar terminology.

3.3.2 Measuring halinity using a 1:5 dilution by volume[1]

Electrical conductivity was measured on selected subaqueous soil samples from South River that had been collected in conjunction with the soil mapping effort. The effort focused on generating halinity data for entire soil profiles so that possible depth trends could be evaluated.

[1] This methods section was adapted from a proposal submitted to the Coastal Zone/Subaqueous Soils Committee of the Northeast Region of the National Cooperative Soil Survey. For the full methodology as written in the proposal, refer to Appendix G.

Subaqueous soil samples that had been frozen since they were described were thawed and then analyzed within two hours. A representative portion of the moist sample was collected using a scoop of fixed volume (15 mL) to which 75 mL of distilled water was added, then mixed thoroughly in a plastic cup (i.e., a 1:5 mixture by volume). The mixture was allowed to equilibrate for two minutes. Electrical conductivity was measured on the unfiltered supernatant ($EC_{1:5}$) and reported as dS/m. At the same time that the sample was prepared to measure conductivity, a duplicate sample was weighed, dried at 105°C, and weighed again to determine the volume of water in the sample (Wv - assumed to be equal to the weight of the water).

$$Wv = \text{wet soil weight} - \text{dry soil weight}$$

A dilution factor was then calculated for each sample based upon the amount of water in the sample and the amount of distilled water added. The measured $EC_{1:5}$ value was multiplied by the dilution factor to determine the porewater EC (EC_{PW}).

$$\text{Dilution factor} = (Wv + \text{volume of water added}) / Wv$$

$$EC_{PW} = EC_{1:5} \cdot \text{dilution factor}$$

The porewater halinity was then calculated using the appropriate conversion factor (Hanson et al., 2006):

$$\text{Halinity (ppt)} = EC_{PW} \text{ (dS/m)} \cdot 0.64 \text{ (for } EC_{PW} \text{ from 0.1 to 5 dS/m)}$$

$$\text{Halinity (ppt)} = EC_{PW} \text{ (dS/m)} \cdot 0.8 \text{ (for } EC_{PW} > 5 \text{ dS/m)}$$

3.3.3 Quality control measures

In order to measure all samples with consistency, we allowed all samples to stand for two minutes after stirring before the EC meter was inserted into the supernatant. Following this procedure meant that, for fine-textured soils, there was clay in suspension at the time of EC measurement. In order to investigate whether or not the suspended clay affected the measured EC, we further examined 16 fine-textured samples. Five mL of soil and 25 mL of distilled water were measured into a 100 mL centrifuge tube and shaken for 30 minutes on an oscillating shaker to facilitate disaggregation. After shaking, samples were allowed to stand for five minutes, after which EC was measured on the supernatant. The same samples were then centrifuged for 10 minutes at 7500 rpm to remove clay from suspension, after which the EC was measured on the same supernatant a second time.

3.4 Results and Discussion

3.4.1 Halinity classification

During the review of halinity classification systems, it became clear that the European systems and the regional systems developed in the US took different approaches. The former, exemplified by the Venice System, sought to provide a common vocabulary for halinity. The classes of the Venice system are one-dimensional, but virtually universally applicable. They provide terms that are communicable but do not impart much specific interpretive value. The mesohaline class always means 5–18 ppt, but a mesohaline subestuary in Maryland behaves differently than one in Florida. By contrast, the regional, ecologically informed systems, such as the one developed for Connecticut coastal soils (Theve, 2014), seek to create terminology that is more information rich. The “low salt marsh soil” class denotes the halinity of a site *and* conveys information about the vegetation and hydrology. The regional systems are concise and efficient in the areas where they are applicable, but since they have been developed independently in different parts of the United States, they cause a proliferation of terms and units that are laborious to compare and synthesize. This problem is unavoidable – regional changes in climate, geology, and hydrology mean that a soil's halinity will not have the same ecological effect in all places.

We have chosen to follow the example of the Venice System and propose halinity classes that can be broadly applied for two reasons. 1) Halinity is an important part of characterizing soils in the coastal zone (subaqueous and otherwise). It should be an aspect of the taxonomy of these soils, and a new soil order for wet soils has already been proposed for inclusion in *Keys to Soil Taxonomy*. So, to be a useful addition to that proposal, halinity classes need to be nationally applicable, and not different from region to region. 2) The purpose of coastal zone soil survey is to provide detailed soils data to support resource management. This means that soils data will be used by other scientific disciplines, most of which use "practical halinity" (ppt) and are familiar with the CMECS or the Cowardin systems (B. Wessel, *personal communication*, June 2020). Using known terminology and class thresholds will improve clarity in interdisciplinary communication. Also, ecological information is included in coastal zone soil surveys via ecological site descriptions, so halinity classes need not bear the responsibility for providing that information. The approach of providing a common vocabulary is more important than conveying ecological information for soils of the coastal zone. Therefore, we propose that the field of coastal zone soil research adopt a modified version of the Venice System

(Table 3.4). It will foster communication with other coastal zone scientists who are familiar with the Cowardin System and CMECS.

Table 3.4. Proposed soil halinity classification system	
Class	Halinity (ppt)
Inland Fresh	<0.5
Fresh	0.5–<5
Mesohaline	5–<18
Polyhaline	18–<30
Euhaline	30–<40
Hyperhaline	≥40

One of the primary considerations in developing this proposed system was the threshold between fresh and brackish subaqueous soils. Currently, *Keys to Soil Taxonomy* defines the upper limit of fresh subaqueous soils (Frasiwassents and Frasiwassists) as 0.2 dS/m, determined by the 1 to 5 dilution by volume method (Soil Survey Staff, 2014), which computes to approximately 1 ppt. The Venice System defines the upper limit of fresh water as 0.5 ppt. Classification tools used by ecologists to assess the quality of estuarine habitats (e.g., the Chesapeake Bay benthic index of biotic integrity (B-IBI)) also use 0.5 ppt to define the upper limit of fresh water (Weisberg et al., 1997). By contrast, recent subaqueous soil research suggests that the upper limit of fresh subaqueous soils should perhaps be higher. The proposed inland fresh class approximates the fresh class of the Venice System. It is based on the work of Erich et al. (2010), which studied freshwater subaqueous soils in (non-coastal) Pennsylvania and reported a maximum $EC_{1:5}$ of 0.05 dS/m, which, if one were to assume saturated soils with 50% porosity, represents halinity of 0.32 ppt. The proposal of 0.5 ppt as the class threshold approximates this value. The proposed fresh class is based on the work of Bakken and

Stolt (2018), which investigated subaqueous soils of freshwater lakes in coastal Rhode Island and reported $EC_{1:5}$ values as high as 0.58 dS/m. Therefore, they proposed that the upper limit of porewater halinity of freshwater soils should be $EC_{1:5}$ 0.6 dS/m, which calculates roughly to 4.8 ppt. Prior to their work, 4.8 ppt would have been considered to be brackish – in the Venice System, and in the Chesapeake Bay B-IBI, it would fall in the oligohaline class. Their proposal has been used to delineate the threshold between freshwater and brackish soils in the taxonomy of Aquasols, the wet soil order that will be integrated into future editions of *Keys to Soil Taxonomy*, so there is precedent to call this range of halinity values fresh, rather than oligohaline. Still, it is worth noting that this delineation is a departure from the classes used by other estuarine scientists, which relate to benthic community health, salt tolerance of fish and SAV, and other factors. The other classes in our proposed system (meso-, poly-, eu-, hyper-) are in common use in the literature. They can be traced back to the Venice System and they are already widely used in the US. The use of these terms will better enable soil scientists to communicate effectively with other scientists (Kristensen & Rabenhorst, 2015).

3.4.2 Developing methodology for determining porewater halinity

This study sought to develop a practical, simple methodology that generates meaningful, communicable data. Method 4.6.5 (1:5 Aqueous Mixture by Volume for Subaqueous Soils) from the Soil Survey Field and Laboratory Methods Manual (SSIR 51; Soil Survey Staff, 2014b) was used as a starting point for the new methodology. Method 4.6.5 is simple, quick, and requires no calculations. It measures electrical conductivity of diluted soil porewater ($EC_{1:5}$) in units of dS/m, so the method can be performed in the field using a portable EC meter. The new methodology proposed here retains the main procedure of Method 4.6.5 and adds steps that allow data to be reported as porewater halinity in units of parts per thousand.

The first issue to address was converting from the EC of the diluted sample ($EC_{1:5}$) to the EC of the porewater (EC_{PW}). Theve (2014) addressed this issue in her study of soil halinity in Connecticut tidal marshes by directly measuring EC_{PW} using a vacuum extraction method, then comparing those data to $EC_{1:5}$ data for the same samples. She ran a power regression between the $EC_{1:5}$ and EC_{PW} datasets, then used the regression function as a conversion factor. This approach was not incorporated into our proposed methodology because it requires practitioners to perform the vacuum extraction method, which is difficult and time-consuming. Balduff (2007) took another approach to the conversion from $EC_{1:5}$ to EC_{PW}. When she measured $EC_{1:5}$, she recorded the wet and dry weight of duplicate samples and used those data to calculate the moisture content of the sample. By knowing the volume of water in each sample, she was able to calculate the magnitude of the porewater dilution in the 1:5 bulk dilution. We incorporated Balduff's approach because recording wet and dry weights is a simple addendum to the $EC_{1:5}$ method. Even if EC is measured in the field, wet weight can be measured with a portable scale, and a sample can be collected to be dried and weighed later.

The second issue to address was converting from EC_{PW} to halinity. In reviewing relevant literature, we found several conversion factors between EC and halinity. Although these vary depending on the composition of solutes in the sample, the most commonly used conversion factors are 1 dS/m = 0.64 ppt for EC values between 0.1 dS/m and 5 dS/m, and 1 dS/m = 0.8 ppt for EC values greater than 5 dS/m (Hanson et al., 2006). These conversion factors were incorporated into the proposed methodology because they are used by Coastal Zone Soil Survey (Payne, 2018).

By incorporating the method of Balduff (2007) to convert from $EC_{1:5}$ to EC_{PW} and widely used conversion factors to convert from EC_{PW} to halinity (ppt), we were able to develop a method that measures $EC_{1:5}$ and, through a few simple calculations, reports in terms of halinity, which facilitates communication with other fields of study in the coastal zone. For a detailed description of the proposed method, refer to Appendix G.

3.4.3 South River halinity

Our proposed methodology for determining soil porewater halinity was applied to 123 soil samples (from 22 pedons) from South River. The halinity values ranged 0.52–23.1 ppt, with a mean of 12.4 ppt and a median of 12.2 ppt (Fig. 3.1). The soil halinity of induvial samples ranges across the fresh, mesohaline, and polyhaline classes. The mean and median values place the soils in the mesohaline class, which matches the classification of the water. (For all South River conductivity and halinity data, refer to Appendix H).

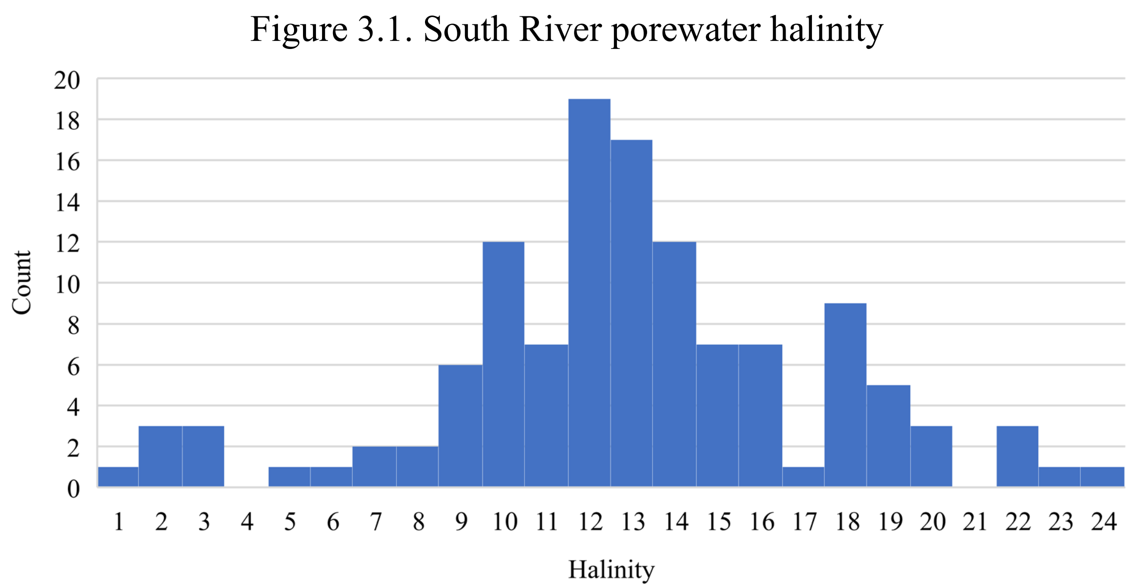


Fig. 3.1. This figure of South River soils porewater halinity shows that most samples had a halinity between 8 and 16 ppt, with a mean of 12.4 ppt and a median of 12.2 ppt, and with some high and low outliers.

3.4.4 Changes in halinity with depth

In most cases, halinity was lowest at the surface and increased slightly with depth, but the change was not significant in the soil control section. The highest halinity values were recorded at depths >150 cm. This finding was unexpected, since the South River watershed is considered a groundwater discharge area (MD Department of the Environment, 2006), where we expected halinity to decrease with depth as groundwater influence became more pronounced. Some profiles did exhibit this expected pattern, but it was counter to the general trend (Fig. 3.2). Still, the change with depth was not statistically significant, so no definitive conclusions could be drawn about the influence of groundwater hydrology.

Figure 3.2. Changes in soil porewater halinity with depth

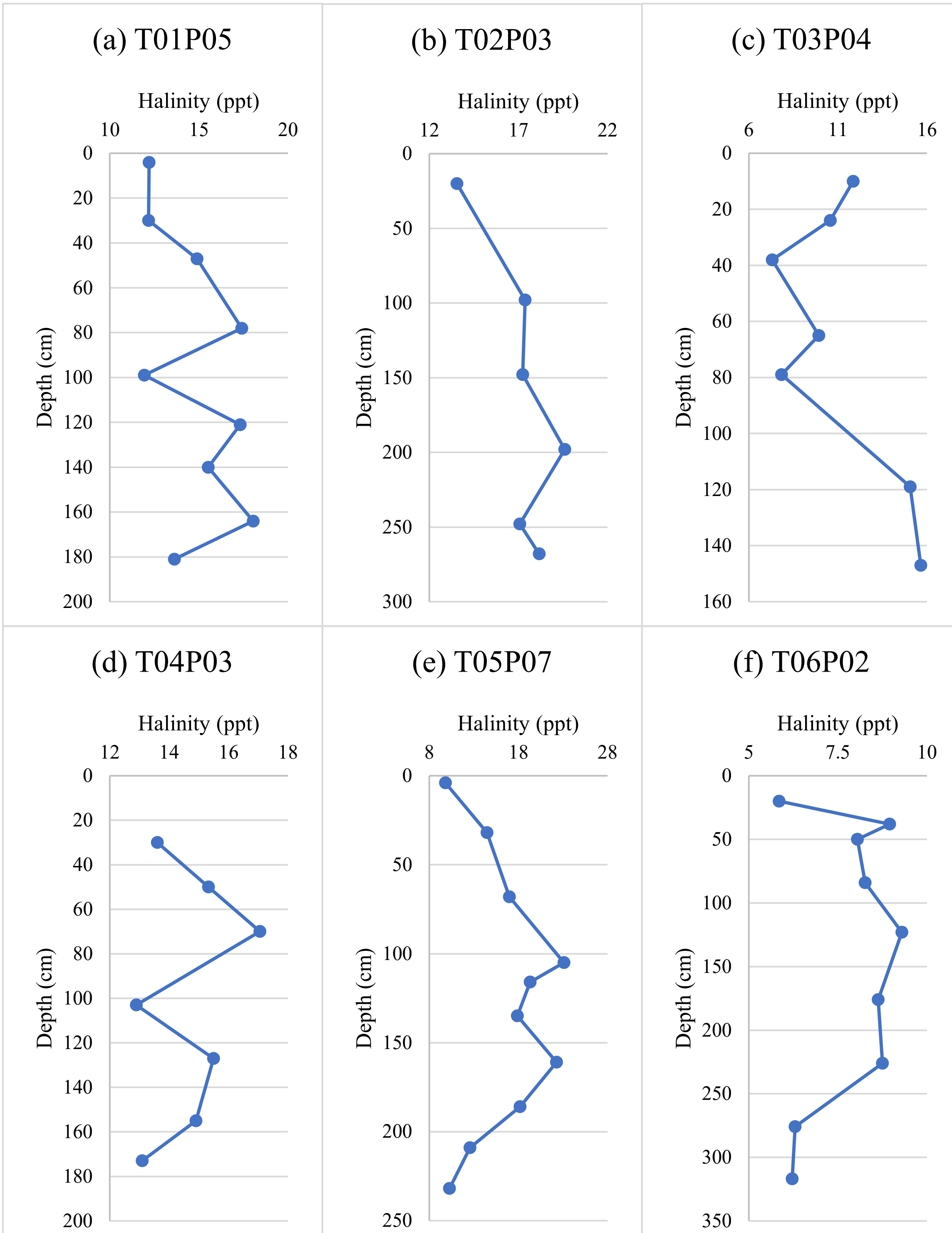


Fig. 3.2. These depth plots represent soil profiles throughout South River and indicate equivocal results. Some profiles exhibited decreasing halinity with depth, which align with our expectation of groundwater influence, but others showed increasing halinity.

3.4.5 Halinity spatial trends

The soils near the river mouth were expected to have the highest halinity because they receive brackish input from the main stem of Chesapeake Bay, but there was no meaningful spatial trend in the halinity. The highest mean halinity was found in one of the transects near the head of the river, but the other transect near the head of the river had the lowest mean halinity. The transects in the river were not significantly different from one another. Soil samples from the central channel had slightly higher halinity than those in the tidal creeks and coves, but the difference was not significant. Furthermore, there was no meaningful trend in the halinity of landforms. The Tidal Creek Platform landform had the lowest mean halinity, but there were no significant differences between the landforms (Fig. 3.3)

Figure 3.3. Surficial soil porewater halinity in South River

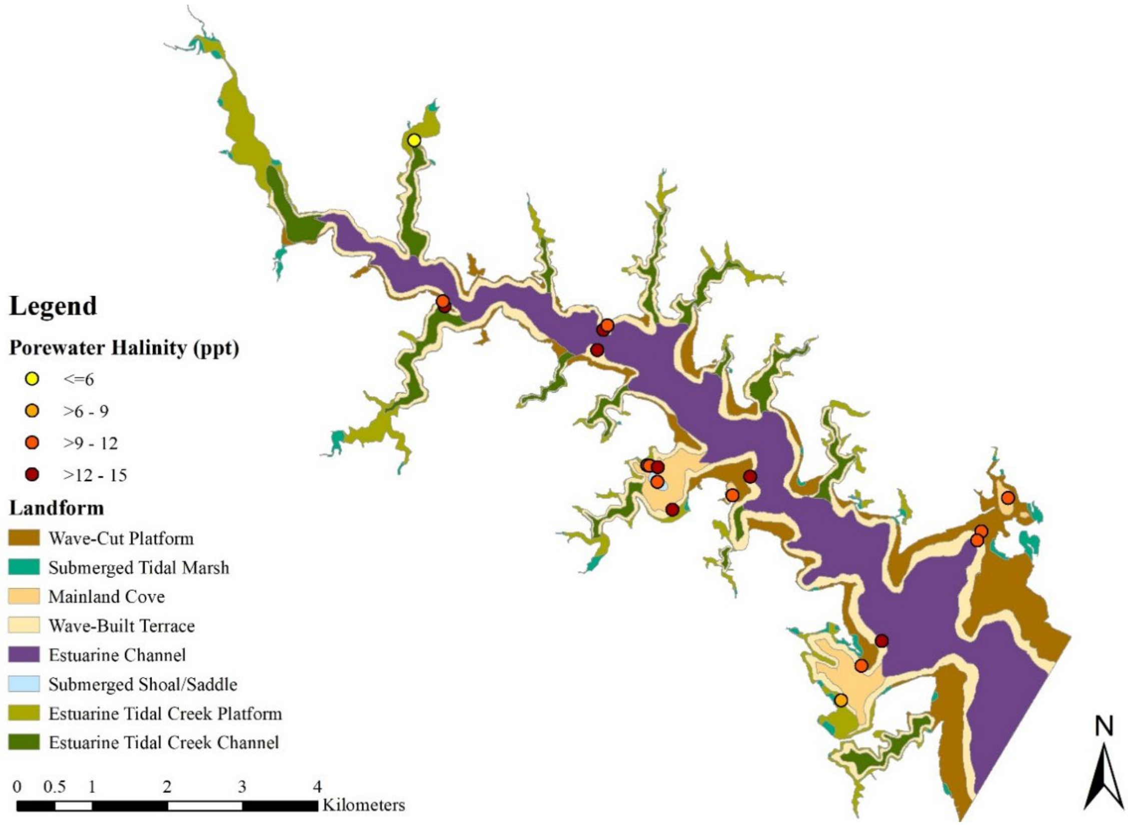


Fig. 3.3. The porewater halinity of surficial soil horizons ranged from 6 to 15 ppt in South River. No significant spatial trend was identified in the halinity measurements.

3.4.6 Unexpected halinity values

The halinity of some of the South River soils was higher than expected based on the halinity of the water; South River is categorized as a mesohaline subestuary (5–18 ppt), but its mean halinity ranges from 7–12 ppt seasonally. Long term data indicate the halinity range of the river is 3–16 ppt (MD Department of Natural Resources, 2020; see Fig. 3.4). The mean and median soil halinity values (12.4 ppt and 12.2 ppt, respectively) aligned with the water halinity, but 23 out of 123 samples had a halinity higher than 16 ppt. Most of these samples (13/23) occurred outside of the soil control section (deeper than 100 cm). The high values could be the result of some unforeseen error in the method, or it could accurately reflect the soil characteristics.

Figure 3.4. South River surface water halinity

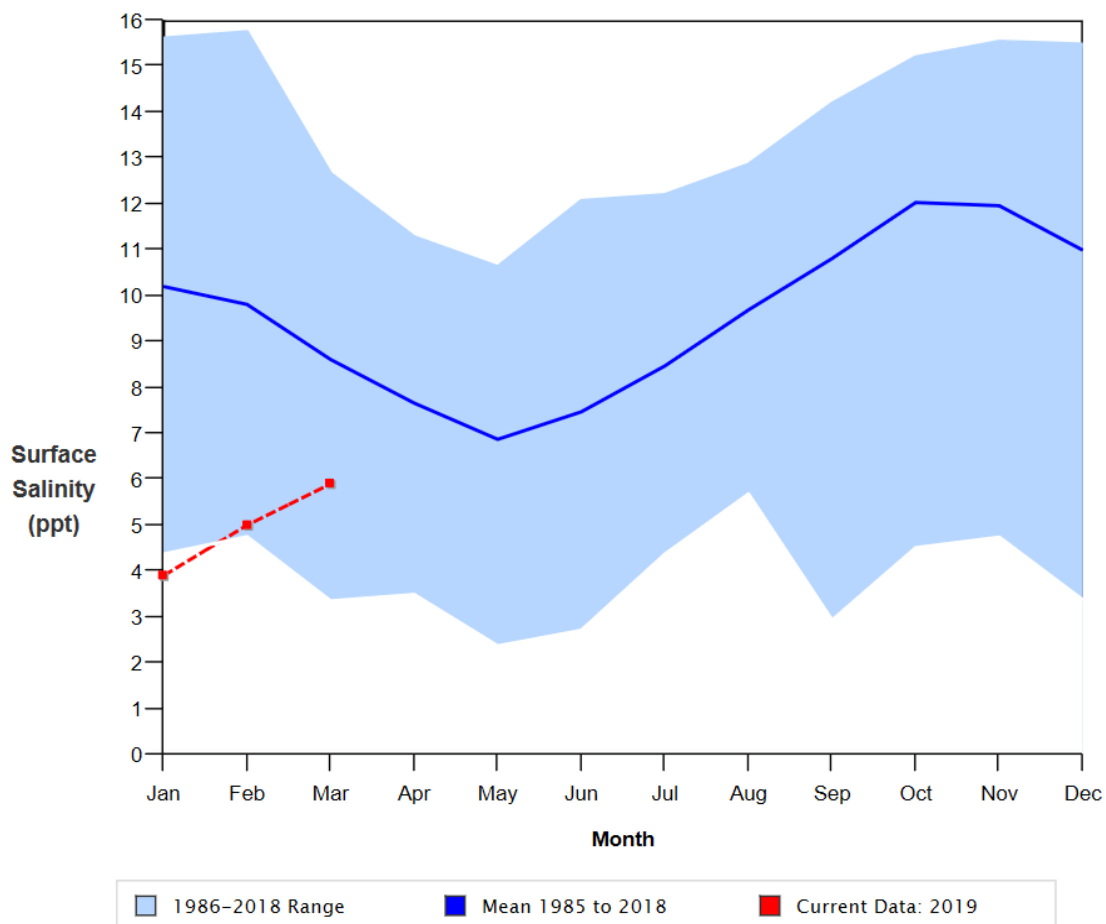


Fig. 3.4. South River surface water halinity ranged from 3 to 16 ppt. (Data courtesy of MD Department of Natural Resources).

3.4.7 Potential sources of error

We investigated several possible sources of error within the methodology. First, it is possible that error was introduced in the measurement of soil water content, which is used to calculate the dilution factor and thereby is part of the conversion from $EC_{1:5}$ to EC_{PW}. The water content measurement was seen as a significant potential source of error because it is the only direct measurement used in the dilution factor formula. In order to assess the potential impact of erroneous water content determinations, percent water was measured on replicate samples. The mean coefficient of variation (CV) for the replicate pairs was 5% (which for pairs of samples is equal to the mean deviation), suggesting that errors in moisture determination would contribute errors of no greater than 5% of the mean. The average of the two replicates was used to calculate the dilution factor for each sample.

We then addressed the question of whether clay suspended in the supernatant of fine-textured soils may cause an increase in the EC measurements. Since clays are charged particles, they could potentially introduce error to the process and falsely inflate the EC measurement. Comparisons of the $EC_{1:5}$ measurements recorded after shaking and after centrifuging the selected fine-textured samples (Table 3.5) indicated that the clay in suspension did not significantly increase the $EC_{1:5}$ of the supernatant. Contrary to expectation, the $EC_{1:5}$ was slightly (and significantly, $p=0.03$ for paired t-test) higher after centrifugation, when all the clay particles had been removed from the supernatant. We postulate that this minor increase could be caused by salts occluded in the pore space of the shaken, but incompletely disaggregated, soils that were moved from the occluded pores into solution by centrifugation.

Table 3.5. $EC_{1:5}$ measurements on porewater from fine-textured samples after shaking ($EC_{1:5s}$) and after centrifuging ($EC_{1:5c}$)			
Sample	$EC_{1:5s}$	$EC_{1:5c}$	Δ ($EC_{1:5c} - EC_{1:5s}$)
T01P03 Ase	1864	1991	127
T01P03 Cseg1	2090	2160	70
T01P03 Cseg2	2280	2470	190
T01P09 2Btsegb1	685	706	21
T01P09 2Btsegb2	371	370	-1
T01P09 2BCsegb	156	160	4
T02P05 Ase1	2450	2480	30
T02P05 Ase2	2490	2560	70
T02P05 Cseg1	2620	2810	190
T02P05 Cseg2	2740	3000	260
T02P05 Cseg3	2930	3200	270
T03P03 2BCb1	1165	1230	65
T03P03 2BCb2	1401	1455	54
T03P03 2Cg	1510	1540	30
T03P03 2C	1811	1930	119
T03P04 2Btb1	830	829	-1
Mean	**1712**	**1806**	**94**
Std Dev	**849**	**918**	**87**

Another potential source of error was the possible oxidation of sulfides in the soils. Pyrite oxidation was viewed as a potential source of excess sulfate because it is a common biogeochemical process that produces sulfate in coastal soils (Fanning and Fanning, 1989; Haering et al., 1989) and can especially be a problem with samples analyzed some extended time after sampling. Efforts were taken to prevent sulfide oxidation in the 2019 samples by storing them on ice in the field and then freezing (-19°C) until they were described and analyzed. The few pedons collected during the 2020 field season were described, sampled, and frozen (-19°C) on the same day they were collected. Evidence of sulfide oxidation can include elevated halinity (because it produces sulfate salts) or acidity (because it produces sulfuric acid). The pH values recorded at the time of EC measurement ranged from 5.72–8.71 for the 2019 samples and from 7.54–9.06 for the 2020 samples, suggesting that the 2019 samples (that had been stored frozen approximately one year) were not more acid than the 2020 samples, which also suggests that sulfide oxidation may not have been a problem.

In order to further explore whether sulfide oxidation might have contributed to some of the higher-than-expected halinity values, extracts from five samples with especially high porewater halinity values were submitted to a water testing lab for sulfate and chloride analysis to determine if they contained excess sulfate. The molar ratio of chloride:sulfate in seawater is 19.4:1, which is a mass ratio of 7.2:1. Due to sulfate reduction (causing sulfate depletion), chloride:sulfate ratios in sediments and marshes can sometimes be greater than 7, but should not be appreciably lower than this (Morris and Riley, 1966). Three of the five samples had chloride-sulfate ratios less than 7:1 (Table 3.6), indicating greater sulfate content in the soil porewater than one would expect if the pore water were to reflect the overlying water column.

In order to further clarify the possible source of the excess sulfate, calculations were made to determine the amount of pyrite in the soil that would need to be oxidized to produce the excess sulfate, which ranged 900–1700 µg/mL (Table 3.6). The calculations indicated the excess sulfate could be accounted for by the oxidation of only 0.01–0.03% pyrite in the soil. The pyrite content observed in the Aquia and Nanjemoy formations ranges from 0.6–0.8% (Rabenhorst & Fanning, 1989), and many tidal marsh soils have pyrite contents of one percent or more. This suggests that oxidation of only a small portion of the pyrite present could be the cause of the excess sulfate measured.

In order to understand the impact of the excess sulfate, calculations were made to determine the amount of conductivity and halinity contributed by the excess sulfate. A review of relevant literature was conducted to find a conversion between sulfate concentration and electrical conductivity. Chang et al. (1983) quantified the relationship thus:

$$[S0_4^{2-}] \text{ (meq/L)} = 13.60 \cdot \text{EC (mS/cm – equivalent to dS/m)}$$

The sulfate concentration of the porewater was converted from units of μg/mL to meq/L using the equivalent weight of sulfate (Hanson et al., 2006). The excess sulfate in the three samples accounted for 1.4–3.1 dS/m EC (1.1–2.5 ppt halinity). Therefore, the halinity produced by the excess sulfate accounted for 5–11% of the halinity of the samples (Table 3.6). Thus, the halinity values would be ~20 ppt if the excess sulfate was removed, which is still substantially above the range expected from the overlying water column (3–16 ppt) (MD Department of Natural Resources, 2020).

Table 3.6. Chloride and sulfate content of South River soil porewater samples and calculations to evaluate potential implications of sulfide oxidation on samples measured with high halinity.

Sample ID	Chloride (μg/mL)	Sulfate (μg/mL)	Excess sulfate (μg/mL)	Excess sulfate (μmol/mL)	Excess sulfate (meq/L)	% moisture	Soil pyrite oxidized for excess sulfate (μg/g)	Soil pyrite oxidized for excess sulfate (%)	EC contributed from excess sulfate (dS/m)	Halinity contributed from excess sulfate (ppt)	Porewater halinity (ppt)	% of EC from excess sulfate
T04P02 Cg1	6900	900	0	0	0	16.9%	0	0.00	0	0.0	21.1	0%
T04P02 Cg3	8200	2100	900	9	19	18.5%	104	0.01	1.4	1.1	21.9	5%
T04P05 2Cg	6800	900	0	0	0	17.2%	0	0.00	0.0	0.0	21.8	0%
T05P07 Cg3	9200	3300	2000	21	42	15.2%	190	0.02	3.1	2.5	23.1	11%
T05P07 C'g2	7400	1900	900	9	19	46.9%	264	0.03	1.4	1.1	22.3	5%

Table 3.6. Chloride and sulfate content were measured on South River soil samples with high halinity (>20 ppt). The analysis was conducted by Water Testing Labs of Maryland (Stevensville, MD). Pyrite content, electrical conductivity, and halinity were derived from excess sulfate in South River soil porewater samples with high halinity. Results indicate that sulfide oxidation occurred in the soil samples, but it does not account for the halinity values being outside the range expected based on the overlying water halinity (3–16 ppt).

The analysis of chloride and sulfate in porewater samples with high halinity suggested that some sulfide (pyrite) oxidation had occurred, despite efforts to prevent it. Although the pyrite oxidation was not sufficient to substantially alter the pH, it nevertheless contributed excess sulfate to the porewater in our analyses. However, the excess sulfate generated by the pyrite oxidation actually had only minor impact on the halinity measurement and did not fully explain the high halinity values measured.

Another potential source of error with the method was the potential loss of porewater from the soil during sampling and processing. Samples were frozen to prevent changes in moisture content, but it is possible that some water drained out of the sample (more likely in coarse-textured samples) or evaporated through the sample bag when the sample was thawed. It is assumed that the porewater is homogenous, so water drainage alone would not change the conductivity (or ionic concentration) of the sample. However, evaporation could concentrate porewater solutes and increase the conductivity of the sample. In such a case, the measured conductivity (and calculated halinity), while accurate for the sample, would not reflect the condition of the soil *in situ*.

That said, we think it is unlikely that water evaporated from the samples because 1) the samples were frozen, and 2) because of the thickness of the plastic storage bags (2 mil thick). There was a weak relationship between the volume of water in the sample and the sample's conductivity ($R^2 = 0.35$) and halinity ($R^2 = 0.06$), which indicates that concentration of solutes in the porewater was not related to the porewater volume, and that evaporation of porewater and concentration of solutes did not occur in the analyzed samples. Nevertheless, this reminds us that in order to avoid potential evaporation and also ensure sufficient porewater volume for EC detection, care should be taken to preserve *in situ* soil moisture content as much as possible by taking measurements on fresh samples, or as quickly after sampling as possible.

3.4.8 Outstanding scientific questions

Without a clear explanation for the high halinity values (which errors are not attributable to problems in methodology), we are left without a good explanation and thus suggest that the question might require further scientific investigation. It might be possible that high soil halinity values are due to some alternate biogeochemical or geophysical dynamic in the South River soils. The unusually high halinity values were recorded for samples below 150 cm, so perhaps solutes are concentrating in the lower substratum due to a water density gradient. The halinity data suggest that fresh groundwater is not counteracting this dynamic. It has been reported that soil halinity can be greater than water halinity depending on environmental factors (Cao et al., 2012; Hughes et al., 2012), so future research could investigate the properties of the soils to determine if some factor is leading to concentration of solutes.

3.5 Conclusions

This study sought to advance establishment of standards for recording and reporting soil halinity. Soil porewater halinity should be reported in terms of parts per thousand in order to facilitate collaboration with other scientific disciplines in coastal settings. This study proposes halinity classes based on the widely accepted Venice System, with modifications that incorporate subaqueous soil research on the threshold between fresh and brackish systems. Porewater halinity can be determined for subaqueous soils using direct measurements of $EC_{1:5}$ and soil moisture content. The proposed method is simple and straightforward, but samples must be processed carefully (and preferably quickly) to minimize sulfide oxidation and to preserve the *in situ* water content as much as possible. This method was successfully executed on South River subaqueous soils, which had a mean halinity of 12.4 ppt and a range of 0.52–23.1 ppt. Because of a handful of unexpectedly high halinity values, we inspected our methodology for potential sources of error. Some evidence of minor sulfide oxidation contributing to sulfate levels in the porewater was found, but it did not explain the high observed halinity. We concluded that the method is reliable, and the resulting data are trustworthy. Further scientific inquiry is necessary to explain the range in halinity found in these soils.

Chapter 4 – Glauconite in South River Subaqueous Soils

4.1 Abstract

The mineralogy of South River soil material types was investigated using grain counts and x-ray diffraction (XRD). None of the material types had sufficient glauconite pellets to be classified as glauconitic according to the current criteria of *Keys to Soil Taxonomy*, but clay-sized glauconite composed a considerable portion of each soil material type. Tertiary material had a mean fine-earth fraction glauconite percentage of over 20%, based on a combination of glauconite pellets and clay-sized glauconite. The findings of this study suggest a need to revise the criteria for glauconitic mineralogy classification to account for clay-sized glauconite.

4.2 Introduction

Mineralogy is a part of soil family classification because of its influence on the physics, chemistry, fertility, and management of soil. Most soils in the inner coastal plain of Maryland generally fall into siliceous (i.e., Sassafras, Woodstown, Fallsington catena; Downer, Hammonton, Hurlock catena) or mixed (i.e., Matapeake, Mattapex, Othello catena) taxonomic families. However, there is a group of soils derived from Tertiary and Cretaceous sediments rich in glauconite, that are classified in glauconitic families (i.e., Annapolis, Donlonton, Colemantown catena). In the South River study area, the surrounding terrestrial soils are derived from glauconite-containing deposits (Glaser, 2002). Also, previous work by Wessel (2020) in the adjacent Rhode River reported soils with glauconitic mineralogy. Therefore, it was anticipated that the mineralogy of the subaqueous soils in South River might be glauconitic.

4.2.1 Glauconite

The South River watershed is underlaid by the Aquia formation, a Paleocene-aged, glauconite-bearing geologic deposit that was formed when the present-day Mid-Atlantic coastal plain was a shallow marine environment (Glaser, 2002). Glauconite is a dioctahedral mica mineral that is widespread in in the Mid-Atlantic region within late Cretaceous and early Tertiary geologic deposits. It is formed in marine environments at low temperatures, usually by the transformation of other phyllosilicates (Fanning et al., 1989). In the Maryland coastal plain, glauconite likely formed from the reaction of sea water and kaolinite and iron oxides that eroded from the Piedmont region, and it is typically found in the form of sand-sized pellets. Glauconite pellet formation may be catalyzed by marine invertebrates. The sediments containing the reactants pass through the organisms' digestive tract and the characteristic glauconite "fecal" pellet is excreted (Fanning et al., 1989). Alternatively, glauconite pellets may from through chemical precipitation, expansion and alteration of detrital mica, or mechanical aggregation (Triplehorn, 1966). Other glauconite morphologies exist, such as vermiform glauconite, which could be a result of phyllosilicates undergoing accordion-like expansion as they are transformed to glauconite.

Glauconite can be distinguished from other mica minerals by the chemical composition of the octahedral sheet. Typically, aluminum occupies the cation sites of the octahedral sheet of dioctahedral phyllosilicates, but in glauconite, the octahedral sheet is dominated by ferric iron (Fanning et al., 1989). In addition to the ferric iron in glauconite's structure, mineralogists have also found small amounts of divalent cations such as magnesium or ferrous iron in the octahedral sheet, and when Bentor and Kastner

(1965) calculated the formula of glauconite, they reported that slightly more than two out of three octahedral cation sites were occupied, which implies that glauconite is not "properly" dioctahedral.

Glauconite's unique chemical composition causes slight structural changes. The presence of ferric iron (a larger ion than aluminum) in the octahedral sheet, the presence of occasional divalent cations, and the occupation of slightly more than two-thirds of the cation sites mean that glauconite has a relatively large d-spacing in the *b* dimension. The primary d-spacing that is used to identify mica is the *d*(001) peak, which is associated with the *c* dimension, but the d-spacing of the *b* dimension impacts the *d*(060) peak, which is used to distinguish between individual mica minerals in x-ray diffraction spectra.

4.2.2 Glauconite in Keys to Soil Taxonomy

The current edition of *Keys to Soil Taxonomy* recognizes glauconitic mineralogy in mineral soils of any particle size family class whose fine-earth fraction contains at least 20% glauconite pellets by weight (Soil Survey Staff, 2014a). In early editions of *Keys to Soil Taxonomy* (prior to 1996), the criterion for glauconitic mineralogy had been a minimum of 40% glauconite by weight, but this was considered by some to be too stringent, and some researchers thought the 40% threshold would exclude recognition of soils that had meaningful amounts of glauconite (Lynn & Yeck, 1985). Lynn and Yeck (1985) proposed that the criteria be rewritten to require at least 15% glauconite pellets in the fine earth fraction, or 10% pellets if glauconite also predominated the clay fraction. Their recommendation was considered, but ultimately a more simplified version was adopted in the 7th edition of *Keys to Soil Taxonomy*, requiring 20% pellets by weight in the fine earth fraction (Soil Survey Staff, 1996). This revision has persisted in subsequent editions. The main advantage of this revision was that it allowed field scientists to identify glauconitic mineralogy in the field. Since glauconite pellets are observable with the naked eye, or a hand lens, field scientists can estimate the glauconite proportion without requiring laboratory analysis. Nevertheless, laboratory methods are usually employed in the determination of mineralogy class.

4.2.3 Identification of sand-sized glauconite with microscopy

While glauconite pellets are observable with the naked eye, they can be quantified more precisely using microscopic techniques like grain counting. Glauconite pellets can be observed under a dissecting or polarizing microscope. They are typically sand-sized (0.05–0.5 mm diameter), lobate grains (Tedrow, 2002). They are usually green but can be orange or brown if exterior iron is oxidized. The grains are opaque under cross-polarized light but can be identified in incident light or plane polarized light by their distinctive morphology. In thin section, they are identifiable by their green color (Fig. 4.1).

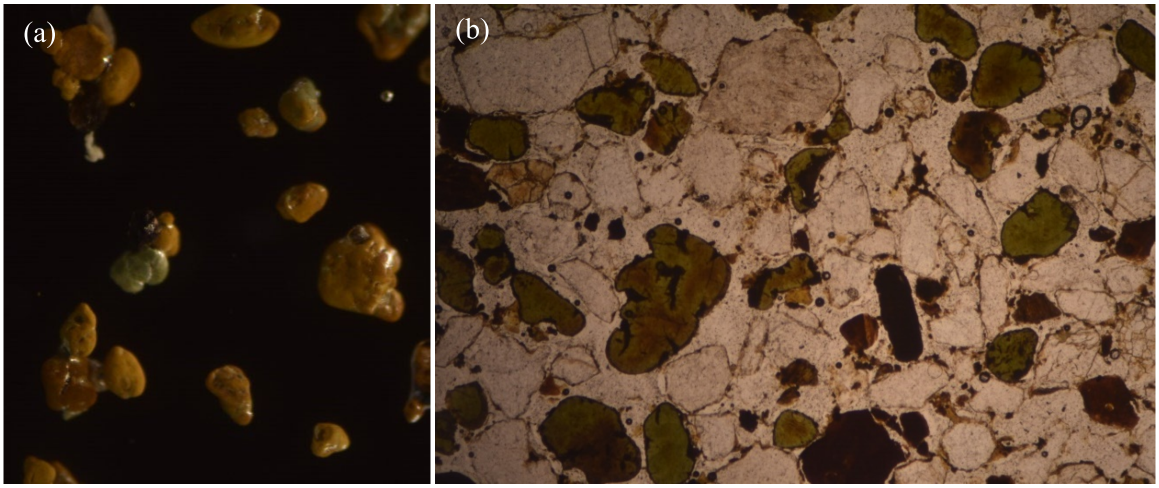


Fig. 4.1. Glauconite grains in a grain mount (a) under incident light; some grains are orange because of iron oxidation. Glauconite (greenish) grains in thin section (b); note the browner inclusions within the green grains that may represent areas with more oxidized iron.

Grain counting techniques are sufficient to identify glauconite pellets and thus to determine if a soil is glauconitic according to the definition in *Keys to Soil Taxonomy*, but they do not provide any insight into the clay mineralogy. This may be important because, although glauconite can be readily seen in pellet form, glauconite may also occur within the clay fraction. Glauconite affects the behavior and chemistry of soils because it has a relatively high cation exchange capacity and usually contains potassium, an essential plant nutrient (Tedrow, 2002). Whatever impact glauconite has on soils, clay-sized glauconite should be more reactive than pellets (Fanning et al., 1989), so a disadvantage of the current criteria for glauconitic mineralogy is that it does not take clay-sized glauconite into consideration at all.

4.2.4 Identification of clay-sized glauconite with x-ray diffraction

X-ray diffraction (XRD) is a semiquantitative analytical technique that is useful for identifying the occurrence of minerals and for estimating their relative proportions. It can be conducted on any particle size fraction and is commonly used in evaluating clays. In XRD scans, mica minerals are distinguished by their *d*(001) peak at 10 Å. Because micas are nonexpansible, the *d*(001) peak remains at 10 Å when Mg-saturated and glycolated, while other 2:1 phyllosilicates, such as smectite and vermiculite, expand with Mg-saturation and glycolation (Fanning et al., 1989). Individual minerals in the Mica group can be distinguished from one another by the *d*(060) peak. Dioctahedral micas, such as muscovite and illite, have their *d*(060) peak at 1.50 Å, while trioctahedral Micas, such as biotite and phlogopite, have their *d*(060) peak around 1.525–1.54 Å (Fanning et al., 1989; Tapper & Fanning, 1968). The trioctahedral micas, which are often absent in soils because of their high weatherability, have a larger d-spacing in the *b* dimension because the divalent cations in the octahedral sheet (commonly Fe^{2+} or Mg^{2+}) are larger than trivalent cations (Al^{3+} or Fe^{3+}) (Fanning et al., 1989). Glauconite's *d*(060) peak is diagnostic because of the mineral's *b* dimension d-spacing falls in between that of other dioctahedral micas and trioctahedral micas. It is not as large as trioctahedral micas, but it is larger than dioctahedral micas because of its ferruginous octahedral sheet and the presence of occasional divalent cations (Bentor & Kastner, 1965; Fanning et al., 1989). The *d*(060) peak for glauconite can vary depending on the degree of iron enrichment but has been reported at 1.511 Å (Bayliss et al., 1986), 1.510–1.515 Å (Tyler & Bailey, 1961), and 1.510–1.520 Å (Bentor & Kastner, 1965). Tapper and Fanning (1968) studied glauconite in Tertiary geologic formations in Maryland and reported the *d*(060) peak at 1.518 Å on average.

The objectives of this study were:

1. To examine the mineralogy of subaqueous soils in the South River estuary, with a particular emphasis on
    a. documenting the presence of Glauconite in sand fractions and
    b. documenting the presence of Glauconite in the clay fractions
2. To determine the appropriate mineralogical family class of subaqueous soils in South River
3. To consider the adequacy of the current criteria for recognizing glauconitic soil mineralogy families in *Soil Taxonomy*

4.3 Methods

4.3.1 Study site

The mineralogical analyses of this study were done within the context of the subaqueous soil survey of the South River, a subestuary on the western shore of Chesapeake Bay (Fig. 4.2). The survey was conducted to inventory the subaqueous soil resources of the South River, and to assess the subaqueous soil-landscape relationship model proposed by Wessel (2020). For a detailed discussion of the study site, refer to Chapter 2.

4.3.2 Sampling locations

A total of 52 soil profiles were sampled throughout South River for the pedological study. The goal of the mineralogical analysis was to characterize the main soil material types found in South River. Wessel (2020) described several material types in Rhode River, and three were found to be widespread in South River: Holocene sands, Holocene fluid fine material, and Tertiary material. Samples from soil horizons were selected from among the 52 pedons of the larger pedological study for mineralogical analysis so that several replicates of each of the 3 major material types were analyzed (Fig. 4.3). In total, 31 horizons from 20 pedons were selected for XRD analysis and 25 horizons from 12 pedons were selected for grain counting.

Figure 4.2. Study site: South River

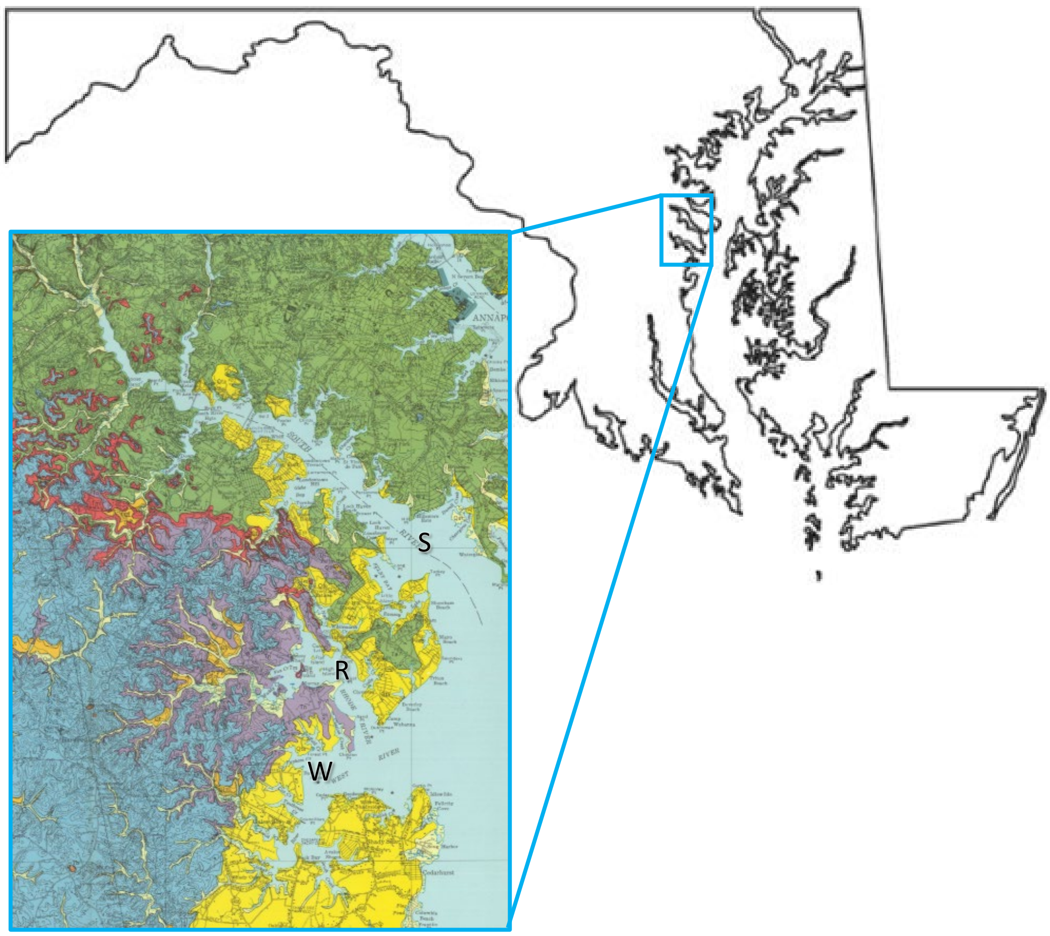


Fig. 4.2. The study site, South River (blue box), is located in Anne Arundel county, Maryland. *Inset*: The Anne Arundel County geologic map detail (Glaser, 1976) shows South River – S (northernmost), Rhode River – R (middle), and West River – W (southernmost). Wessel (2020) surveyed Rhode River and West River, which are underlain by the Nanjemoy formation (shown in purple). South River is underlain by the Aquia formation, which is a similar, glauconite-bearing deposit (shown in green). The yellow areas represent Quaternary deposits that overlie the Tertiary formations.

Figure 4.3. Sampling waypoints in South River selected for mineralogical analysis

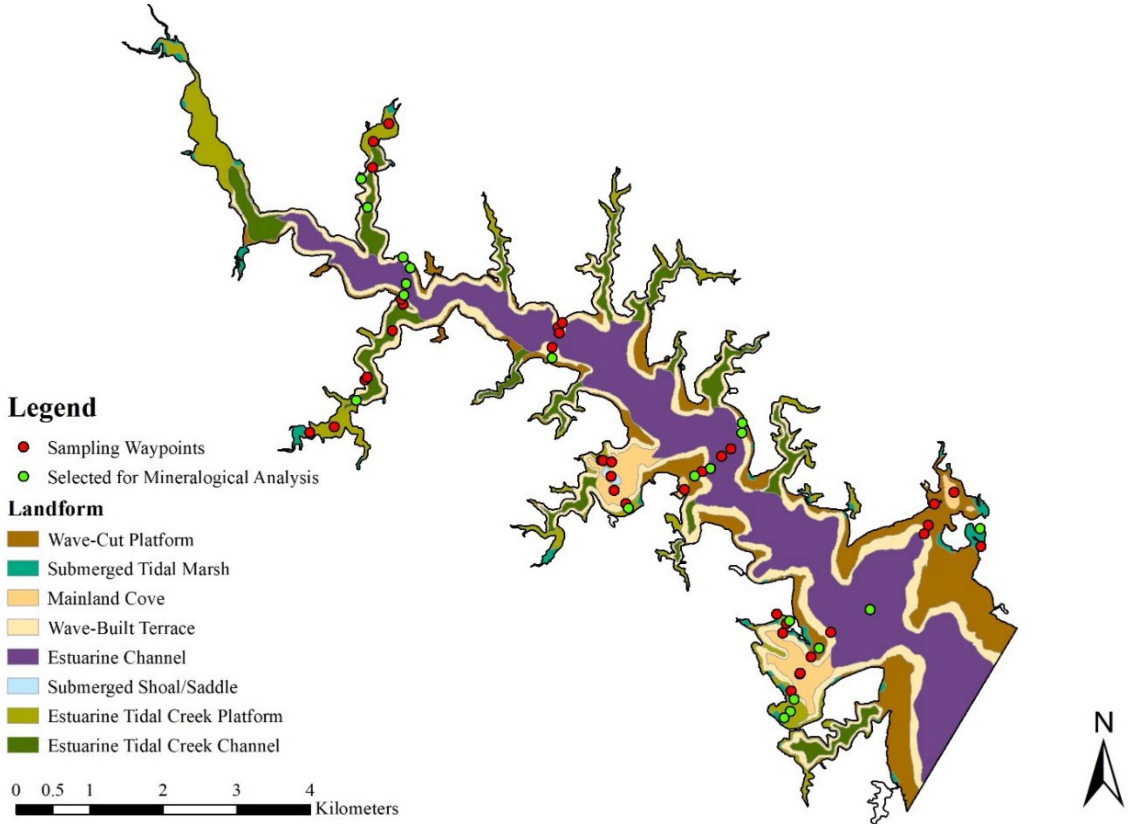


Fig. 4.3. Sampling locations in South River. The green dots represent the pedons selected for mineralogical analysis.

4.3.3 Analysis of the sand

Preliminary investigations indicated that glauconite was essentially absent from the silt fraction, so the focus was placed on the sand and clay fractions. Grain counting was used to document the sand mineralogy, following the method described by Balduff (2007). During particle size analysis, sands were separated into fractions (very coarse, coarse, medium, fine, very fine) and the three most abundant fractions (which typically accounted for at least 75% of the total sand fraction) were selected for grain counting. Grain mounts were prepared using Meltmount^{TM} Quick-Stick^{TM} (Cargille Laboratories, Inc., Cedar Grove, NJ) with a refractive index of 1.539, and minerals were identified using a polarizing microscope (Carl Zeiss Microscopy, LLC). A minimum of 300 grains were counted for each slide/fraction. After grain counts were completed, the glauconite content of the sand was calculated using a weighted average based on the proportional weight of each sand fraction used (see Appendix J).

The grain counts provided a numerical percentage of the volumetric content of glauconite in the sample, but since glauconite has a slightly higher specific gravity than quartz (2.79 g/cm^3 and 2.65 g/cm^3, respectively) (Bentor & Kastner, 1965), it was assumed (conservatively) that if glauconite constituted 20% of the counted grains, the glauconite would be at least 20% of the sample by weight (since the rest of the sample was mainly quartz).

4.3.4 Analysis of the clay

Clays were separated via sedimentation and centrifugation. Oriented clay mounts of both K- and Mg-saturated samples were made using the method of Drever (1973), and the Mg-saturated mounts were also glycolated. The oriented clay mounts were scanned from 2–30° 2θ at a rate of 0.77° 2θ per minute (total scan time 36 minutes) using a Panalytical PW1830 X-ray diffractometer equipped with a Cu tube and a curved crystal graphite monochromator and a sealed Xe proportional detector (Philips Analytical, B.V.; Almelo, NL). The scans were recorded using X'Pert System software (v. 1.3d, 2001; Philips Analytical, B.V.; Almelo, NL). The K-saturated samples were scanned three times: when air dry at 25°C, after heating to 300°C, and after heating to 550°C.

In order to better identify the mica minerals, additional high-angle scans were performed to view the *d*(060) peak. Several reference glauconite samples were collected from soils on the Aquia and Nanjemoy formations in order to document the d-spacing of the *d*(060) peak for local glauconite (Fig. 4.4). These included material from pedon RR19 (38.88524, -76.52367) from the Rhode River study, C horizon material from a road cut on Rte. 468 (38.884761, -76.568709), C1 horizon material (41–57 in) from pedon S66MD16–2–5 (approximately 38.972, -76.777), and C horizon material (235–240 cm and 260–265 cm) from the Collington soil series (38.8565331 -76.7815933).

Glauconite pellets from these samples were physically separated by hand under a 10x dissecting microscope (Carl Zeiss Microscopy, LLC), then crushed with a mortar and pestle. The samples were spiked with one part lanthanum hexaboride (LaB_6) to six parts soil and prepared as random powder mounts. Lanthanum hexaboride is highly crystalline and has a distinctive peak at 1.469 Å (near to the location of the mica d(060) peak), so it can be used to align the XRD scan and correct for peak shifts due to the machine geometry. They were scanned from 60.5–64.0° 2θ at a rate of 0.06° 2θ per minute (total scan time of one hour).

Similar high-angle scans (60.5–64° 2θ) were run on random powder mounts of selected South River clays (similarly spiked with LaB_6) to document the d-spacing of the d(060) peak in order to identify specific mica minerals present in the clays.

Figure 4.4. Glauconite reference sample locations

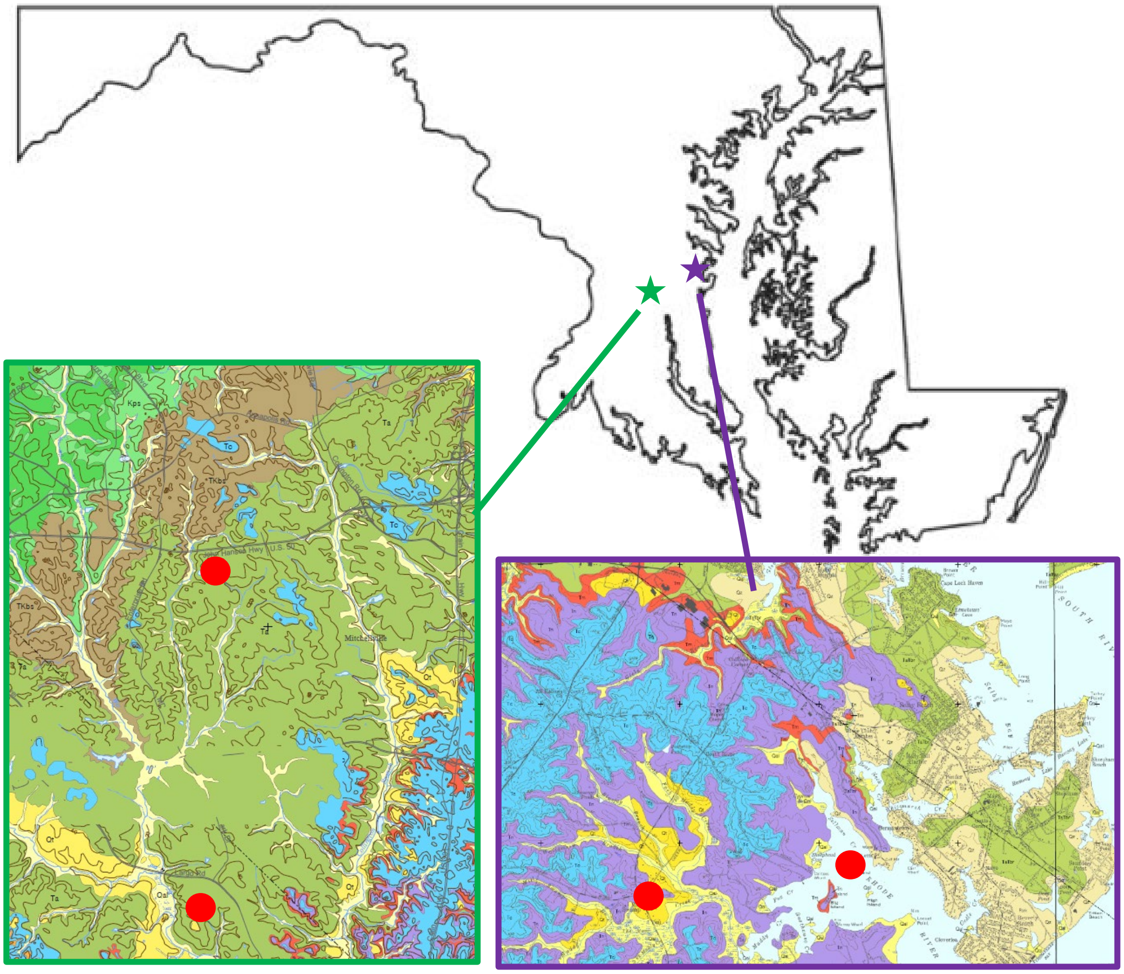


Fig. 4.4. Map of Maryland with glauconite reference sample locations marked in red (*inset*). Two reference samples were collected in Anne Arundel Co. (*purple star*), from soils formed in the Nanjemoy Formation. Two others were collected in Prince George's Co. (*green star*), from soils formed in the Aquia Formation. Inset maps courtesy of Maryland Geological Survey (Glaser, 2002; Glaser, 2003).

4.3.5 Mineral estimations

XRD spectra were exported to Microsoft Excel (Microsoft Corporation, 2016) and the presence and abundance of various clay minerals was estimated using *Mineral Powder Diffraction File Data Book* (Bayliss et al., 1986) and other reference materials.

The proportions of the various clay minerals were estimated by comparing the relative peak sizes (height and area) in the XRD spectra. Since XRD is considered a semi-quantitative analysis, the following system (Table 4.1) was used to approximate upper and lower bounds of mineral proportions, in order to avoid reporting with precision unwarranted by the method.

Table 4.1. Mineral estimation system

Mineral Proportion	Designation
Trace	tr
<10%	X
10-30%	XX
30-70%	XXX
>70%	XXXX

4.4 Results and Discussion

4.4.1 Sand mineralogy

Grain counting indicated that the sand fraction of the subaqueous soils in South River was predominantly quartz, which constituted 73% of the sand fraction on average (range 47–93%). All three material types had similar sand fraction quartz contents (83% for Holocene sands, 71% for Holocene fluid fines, and 70% for Tertiary material), but the Holocene fluid fines tended to be much lower in sand (13–37%) compared to the other two material types (58–96% for Holocene sands and 50–84% for Tertiary material).

The percentage of glauconite pellets in the sand fraction differed significantly between the various material types, ranging from 1.2 to 53%, and five (out of 25) of the samples had more than 20% glauconite pellets in the sand fraction. There was very little glauconite observed in the sand fraction of Holocene fluid fine material (0.02% on average), while the Holocene sands averaged 9.1% glauconite pellets (range 2.4–19%), and the Tertiary materials averaged 20% glauconite in the sand fraction (range 3.8–36%).

4.4.2 Clay mineralogy

The local glauconite reference samples demonstrated that the *d*(060) peak for glauconite is at 1.518 Å (~61.0° 2θ). The high-angle scans conducted on the reference samples showed a strong peak at 1.518 Å and a slight plateau around 1.499 Å (~61.7–61.8° 2θ) (Fig 4.5). This corroborated the *d*(060) peak location reported by Tapper and Fanning (1968) and provided justification to use 1.518 Å as the glauconite peak location in the high-angle scans on South River samples.

Figure 4.5. Glauconite reference samples

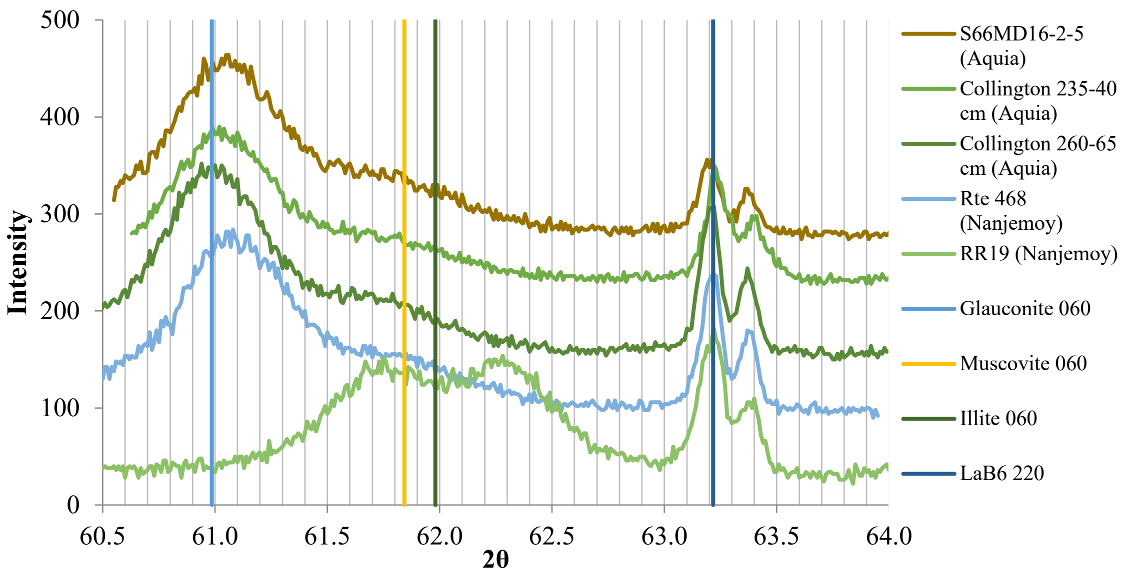


Fig. 4.5. The compiled XRD scans of crushed glauconite pellets isolated from soils formed in glauconitic sediments (Aquia and Nanjemoy formations) show a strong glauconite peak at 1.518 Å (~61.0° 2θ). The vertical lines on the graph are reference locations for the *d*(060) peak of the mica minerals glauconite, muscovite, and illite (*left to right*) (Bayliss et al., 1986). The blue vertical line (*far right*) is the LaB_6 reference location and the two sharp peaks at 1.469 Å (~63.25° 2θ) are the LaB_6 peaks (K_α (left) and K_β (right)), which are used to correct any shifts due to minor errors in machine geometry and to accurately align the scan.

The high-angle scans conducted on selected South River clay samples showed peaks at 1.518 Å, indicating that glauconite was the specific mica mineral present (Fig. 4.6). Of the five selected samples, three show that the mica is dominantly glauconite (>90%), one shows approximately 70% glauconite, and one shows more illite (60%) than glauconite (40%). From these data, we inferred that the mica in South River clays is primarily glauconite.

Figure 4.6. South River clay high-angle scans

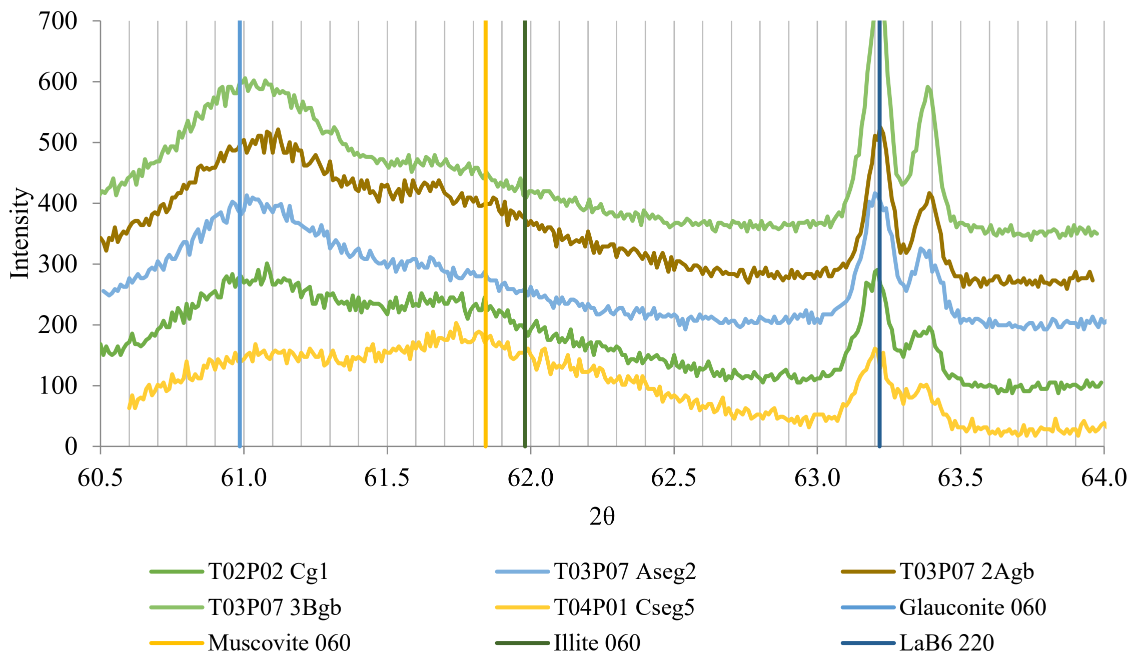


Fig. 4.6. The high-angle (60.5–64.0 2θ) scans conducted on selected South River clays demonstrated that glauconite is the main mica mineral present in the clay fraction.

The 2–30° 2θ XRD scans indicated that the clay fractions of the South River soils contained significant amounts of mica, regardless of soil material type. Based on the information from the glauconite reference samples and high-angle scans on South River soils, we understood the mica to be mainly glauconite. Twenty-seven out of 31 oriented clay mounts were designated “XXX”, indicating 30-70% glauconite (for XRD spectra and mineral estimation tables, refer to Appendix I). In addition to designating the upper and lower bounds of glauconite content, we also estimated the percent glauconite in each sample by determining the proportions of other minerals present in the XRD spectra. The glauconite proportion in the clays did not differ significantly between material types. The mean glauconite proportion of the clay fractions was 54% for Holocene sands, 42% for Holocene fluid fine material, and 40% for Tertiary material. Holocene sand samples were lower in clay percentage than the other material types (2.1–18% clay, compared to 16–37% for Holocene fluid fines and 11–42% for Tertiary material), so clay-sized glauconite was not as prevalent in that material type.

4.4.3 Total glauconite content of the samples

Total glauconite content was estimated for the samples using a weighted average of the clay and sand glauconite based on particle size analysis data (Table 4.2). Of the 25 samples which underwent grain counting, three samples (all of which were Tertiary material) had more than 20% glauconite pellets in the fine-earth fraction (present definition of glauconitic in *Keys to Soil Taxonomy*). Nine more samples had more than 17% total glauconite based on a combination of pellets and clay-sized glauconite. Considering the uncertainties associated with the methods of mineral estimation, these samples were considered close enough to the 20% threshold to be counted as glauconitic.

Table 4.2. Total estimated glauconite content of South River soil samples based on combined analysis of grain counting of sands and XRD of clays.								
		A	**B**	**C**	**D**	**E**	**F**	**G**
Sample	Material Type	% Sand	Glauconite pellets in sand fraction	Glauconite from sand (%age of fine-earth fraction) **(A • B)**	% Clay	Glauconite in clay fraction (estimated from XRD spectra)	Glauconite from clay (%age of fine-earth fraction) **(D • E)**	Estimated total glauconite in sample **(C + F)**
T01P04 Ase **	Holocene Fluid Fines	12.9%	No Data	No Data	36.1%	50%	18%	18%
T02P04 Cseg2	Holocene Fluid Fines	36.9%	0.0%	0.0%	26.1%	40%	10%	10%
T05P03 Ase2	Holocene Fluid Fines	13.1%	0.0%	0.0%	15.7%	25%	3.9%	3.9%
T05P09 Cseg1	Holocene Fluid Fines	24.2%	0.09%	0.02%	21.9%	40%	8.8%	8.8%
T06P04 Aseg	Holocene Fluid Fines	17.4%	0.0%	0.0%	18.7%	50%	9.4%	9.4%
T06P05 Ase3 **	Holocene Fluid Fines	30.1%	0.0%	0.0%	36.6%	45%	17%	17%
T01P06 Aseg	Holocene Sands	90.2%	7.6%	6.8%	7.2%	60%	4.3%	11%
T01P06 Cseg1 **	Holocene Sands	77.9%	13.5%	11%	16.6%	50%	8.3%	19%
T01P06 Cseg2	Holocene Sands	91.9%	9.0%	8.2%	5.3%	60%	3.2%	11%
T02P02 Cg1	Holocene Sands	89.0%	13.0%	12%	5.2%	40%	2.1%	14%
T02P07 AC'b	Holocene Sands	80.2%	1.2%	1.0%	12.8%	60%	7.7%	8.7%
T03P07 Ase2 **	Holocene Sands	81.2%	13.8%	11%	14.2%	65%	9.2%	20%
T03P07 Ase3 **	Holocene Sands	88.4%	18.4%	16%	7.9%	60%	4.7%	21%
T04P01 Cseg5	Holocene Sands	58.1%	14.0%	8.2%	14.4%	33%	4.8%	13%
T05P08 Cseg1 **	Holocene Sands	75.0%	22.9%	17%	18.3%	40%	7.3%	25%
T05P08 ACg	Holocene Sands	93.3%	6.9%	6.5%	5.5%	50%	2.8%	9.2%
T05P08 C'seg1	Holocene Sands	96.1%	2.7%	2.6%	2.1%	60%	1.3%	3.9%
T05P10 Ase	Holocene Sands	88.8%	6.5%	5.8%	7.1%	55%	3.9%	9.7%
T05P10 Aseg	Holocene Sands	82.5%	2.7%	2.2%	12.1%	50%	6.1%	8.3%
T05P10 Cseg1	Holocene Sands	96.4%	6.4%	6.2%	2.4%	75%	1.8%	8.0%
T05P11 Cseg2	Holocene Sands	73.6%	2.4%	1.8%	9.2%	50%	4.6%	6.4%
T02P07 2Ab	Tertiary Material	84.1%	0.1%	0.1%	11.0%	50%	5.5%	5.6%
T03P07 2Btgb **	Tertiary Material	72.0%	21.7%	15.6%	15.9%	60%	9.5%	25.2%
T05P11 2BCb	Tertiary Material	75.5%	5.1%	3.8%	18.3%	40%	7.3%	11.2%

T01P10 2Btsegb **	Tertiary Material	57.9%	11.2%	6.5%	37.0%	60%	22.2%	28.7%
T01P11 2BCsegb **	Tertiary Material	49.7%	13.0%	6.5%	41.6%	50%	20.8%	27.3%
T01P12 2Btsegb1	Tertiary Material	69.5%	16.4%	11.4%	22.0%	No Data	No Data	11.4%
T01P12 2Btsegb3 *	Tertiary Material	67.7%	52.5%	35.6%	29.7%	20%	5.9%	41.5%
T02P08 2BC1 *	Tertiary Material	78.8%	26.2%	20.6%	16.5%	No Data	No Data	20.6%
T02P08 2BC2 *	Tertiary Material	82.1%	34.3%	28.2%	13.9%	0.0%	0.0%	28.2%

Table 4.2. The values in this table represent sand and clay fraction glauconite calculations based on the % sand and % clay in each sample.Samples marked with (*) met the current criteria of *Keys to Soil Taxonomy* for glauconitic mineralogy (>20% pellets). Samples marked with (**) surpassed 17% total glauconite and should be considered glauconitic.

4.4.4 Total glauconite content of sampled pedons

The glauconite content of the mineralogy control section (0–100 cm) was calculated for the twelve pedons for which both sand and clay mineralogical data were generated. Glauconite content for the control section was calculated according to the standard approach of using a weighted average based on horizon thickness and the glauconite content of the horizon. The glauconite content of horizons in the control section that had not been sampled was estimated based on the soil material types that were present and particle size data. First, the material type of the horizon was determined. Next, the clay percentage of the horizon was multiplied by the average clay fraction glauconite percentage of the material type (54% for Holocene sands, 42% for Holocene fluid fines, and 40% for Tertiary material). Then, the horizon's sand percentage was multiplied by the mean sand fraction glauconite percentage of the material type (9.1% for Holocene sands, 0.02% for Holocene fluid fines, and 20% for Tertiary material). Then, the calculated glauconite percentages for the horizon's clay and sand fractions were added together, and that total horizon glauconite content was integrated into the calculation of glauconite in the fine-earth fraction. None of the twelve sampled pedons had a weighted average of 20% glauconite pellets in the fine-earth fraction, but two pedons had at least 18%. When clay-sized glauconite and glauconite pellets were included together in the calculations, three of the twelve sampled pedons had more than 20% glauconite, and three additional pedons had at least 18% (Table 4.3). Considering the uncertainties of the methodologies for mineral estimation, it can be argued that these pedons should also be considered glauconitic. The pedons that had glauconitic mineralogy were found on numerous landforms in South River including wave-cut platforms, tidal creek platforms, submerged tidal marshes, and submerged shoal/saddles. Therefore, several of the proposed soil series developed in the pedological survey were classified as glauconitic: Glebe Bay, Long Point, Overboard, and South River (see Appendix F).

The fact that some pedons surpassed 20% glauconite when clay-sized glauconite was included suggests that inclusion of the clay fraction merits consideration when assessing the mineralogy of soils formed in glauconite-bearing materials.

Table 4.3. Total glauconite content of South River pedons			
Pedon	Landform	Associated Series	Total Glauconite in Ctrl Section
T01P06 *	Wave Cut Platform	South River	18%
T01P10 *	Wave Cut Platform	South River	23%
T01P11 *	Wave Cut Platform	South River	18%
T02P02	Wave Cut Platform	South River	12%
T02P08 *	Wave Cut Platform	South River	22%
T05P11	Wave Cut Platform	South River	11%
T02P07	Wave Built Terrace	Duvall Creek	11%
T04P01	Wave Built Terrace	Duvall Creek	11%
T05P08	Wave Built Terrace	Duvall Creek	12%
T05P10	Wave Built Terrace	Duvall Creek	8%
T03P07 *	Tidal Creek Platform	Overboard	19%
T01P12 *	Submerged Tidal Marsh	Long Point	26%

Table 4.3. This table shows the total glauconite content of the selected pedons, the landform where they were sampled, and the proposed soil series mapped at their sampling location. Pedons marked with (*) are considered glauconitic because they had a weighted average of ≥18% glauconite.

4.5 Conclusions

Grain counting and x-ray diffraction demonstrated that the subaqueous soils of South River contained glauconite pellets and clay-sized glauconite. The glauconite pellet content of the sand fraction differed between the material types. The Holocene fluid fine material had almost no pellets, but the Holocene sands had 9% pellets in the sand fraction on average, and the Tertiary material had an average of 20% pellets in the sand. The proportion of glauconite in the clay fraction was more consistent among the three major material types with all three containing 40–50% glauconite.

None of the soils evaluated in this study could be classified in the glauconitic mineralogy family class based on the current criteria in *Keys to Soil Taxonomy* (>20% glauconite pellets in the fine-earth fraction), although two pedons were close to meeting the requirement. When we included clay-sized glauconite with glauconite pellets to calculate glauconite content, approximately half of the sampled pedons met (or were close to) the 20% threshold. Those glauconitic soils were generally found in shallow, high-energy areas of South River, such as wave-cut platforms and submerged tidal marshes, where Tertiary material was present in the mineralogy control section.

Finally, because clay-sized glauconite constituted a considerable portion of the total glauconite in the South River soils, and because the clay-sized glauconite would likely be even more reactive than the sand-size pellets, we believe that inclusion of clay-sized glauconite in the criteria for the glauconitic mineralogy family class merits consideration.

Chapter 5: Thesis Conclusions

This study demonstrated that pedological protocols are effective in subaqueous settings and they enrich coastal zone research. The soil-landscape paradigm can be used to predict the distribution of subaqueous soils.

The Rhode River conceptual soil-landscape relationship model provided useful guidance for mapping subaqueous soils in South River. It successfully predicted the distribution of soil material types (Holocene sands, Holocene fluid fines, and Tertiary material), which provide a general estimation of soil characteristics, including texture and fluidity; and inform resource management, including suitability for aquaculture, SAV restoration, or dock or marina construction. The usefulness of the Rhode River model indicated that pedological protocols are effective in subaqueous settings.

Soil-landscape models become more effective when they integrate new information. The analysis of South River soils demonstrated that hypersulfidic materials are present throughout South River, but especially on wave-built terraces, estuarine channels, tidal creek channels, and tidal creek platforms, where Holocene sands and Holocene fluid fines were predominant. The soil-landscape model developed by Wessel (2020) can be made been more useful for other western shore Chesapeake Bay subestuaries by incorporating our analysis of hypersulfidic materials, which were less prevalent in Rhode River.

This study addressed aspects of subaqueous soil classification, a present issue as this burgeoning field of study works towards standardized methods and terminology. In the US, this is most evident in the development of Aquasols, a new wet soil order (that includes subaqueous soils) that has been proposed as an addition to *Keys to Soil Taxonomy*, and in the efforts made by the National Cooperative Soil Survey to capture subaqueous soils in the Coastal Zone Soil Survey. Subaqueous soil science is a relatively young field of study, and developing standardized methods and classification is an ongoing effort. The method of halinity measurement proposed in this study is simple and straightforward yet produces data that reflect the condition of the soil and are easily communicable with interdisciplinary collaborators. The method was successfully tested on soil samples from South River. If samples are processed carefully (and quickly), and care is taken to prevent sulfide oxidation and preserve *in situ* moisture content, then reliable, meaningful data can be generated with relative ease. The proposed halinity classification system, based on the Venice System, with modifications that incorporate recent subaqueous soil research, also prioritizes facilitating communication with other coastal zone scientists.

This study also investigated mineralogical classification – specifically, the criteria for the glauconitic mineralogy family class. The mineralogical analysis of South River soils indicates that the criteria for the glauconitic mineralogy family class in *Keys to Soil Taxonomy* should be revised. None of the soils evaluated in this study could be classified as glauconitic based on the current criteria in *Keys to Soil Taxonomy* (>20% glauconite pellets in the fine-earth fraction), but when clay-sized glauconite was included in the calculation of glauconite content, approximately half of the sampled pedons had 20% total glauconite. Because clay-sized glauconite constituted a considerable portion of the total glauconite in the South River soils, and because the clay-sized glauconite would likely be even more reactive than the sand-size pellets, we believe that inclusion of clay-sized glauconite in the criteria for the glauconitic mineralogy family class merits consideration.

This study demonstrates that pedological paradigms and techniques enrich the study of subaqueous environments. Soil-landscape relationship models can be used to predict soil distribution and statistically evaluate soil surveys. As research continues, this approach will continue to be refined, providing better tools to support soil survey and resource management in subaqueous settings.

Appendix A. Pedon Descriptions

Explanations of the abbreviations used in the descriptions can be found in *Field Book for Describing and Sampling Soils* (Schoeneberger et al., 2012). Coordinates are in decimal degrees.

			Colour				Texture						Peroxide Change		Odor		Fragments		Redox Features					
Horizon	Bottom Depth (cm)	Boundary Distinction	%age	Hue	Value	Chroma	Field Texture	PSA Texture	% Sand	% Silt	% Clay	Fluidity Class	3%	30%	Kind	Intensity	Kind	%age	Kind	%age	Contrast	Hue	Value	Chroma
SP01 (38.943299, -76.576631)																								
Ase1	20	C		10Y	2.5	1	L					VF	Y	SL	PC	MO								
Ase2	48	A		5GY	2.5	1	L					VF	Y	SL	HS	SL	shell	1						
Cseg1	74	C		5GY	2.5	1	L					MF	Y	SL	PC	SL	shell	1						
Cseg2	107	C		N	2.5	0	L					VF	Y	ST	PC	MO	shell	1						
Cseg3	145	C		10GY	2.5	1	L					VF	Y	SL	PC	SL	fiber	1						
Cseg4	168			5G	2.5	1	L					SF	Y	SL	PC	SL	fiber	2						
																	shell	2						
SP03 (38.914663, -76.509447)																								
Ase	7	C		10Y	2.5	1	Mky SL	LS	83.4	3.9	12.7	NF	Y	SL	HS	ST	roots	20						
Oe	27	C		7.5YR	2.5	2	Mky peat					NF	N	NE	HS	ST	roots	60						
2A'se	46	C		10Y	2.5	1	Mky SL	fSL	61.8	19.9	18.4	MF	N	NE	HS	ST	roots	15						
2Eseg	55	G		10Y	5	1	SL	fSL	69.2	22.7	8.2	NF	N	VS	HS	SL	roots	15						
2Btseg1	69	C		5GY	4	1	SCL	SCL	56.6	20	23.3	SF	N	VS	HS	SL	roots	10	concentration		D			
2Btseg2	86	C		5G	4	1	CL	C	40.9	8	51.1	NF	N	SL			roots	5	concentration		D	10YR	5	3
2Btseg3	117			10Y	4	2	C	SC	52.1	8.4	39.5	NF	N	ST			roots	10	concentration		D			
			or	5G	3	2											gravel	5						
SP04 (38.915505, -76.511488)																								
Ase	11	C		5Y	3	2	Mky SL	SL	70.7	10.7	18.5	SF	Y	SL	HS	ST	roots	15						
ABseg1	21	G		2.5Y	4	1	SL	fSL	78.1	13.7	8.3	SF	N	SL	HS	MO	roots	10						

ABseg2	31	C		10Y	4	1	SL	fSL	73.9	14.1	12	NF	Y	VS	HS	MO	roots	15						
Btg1	50	C		5GY	4	2	SL/SCL	SCL	64.3	13.2	22.5	SF	Y	SL			roots	15	concentration	8	P	10YR	4	6
Btg2	66	C		10GY	3	1	SCL	SC	54.9	8.9	36.2	SF	Y	SL			roots	10	concentration		P	10YR	3	4
																	gravel	5						
BCt	78	C	matrix	5Y	4	3	SCL	SC	51.6	7.9	40.4	NF	Y	VE										
			15	10GY	3	1																		
BCtg	116		matrix	10Y	4	2	SCL	SC	53.2	7.5	39.3	NF	Y	VE					concentration	12	D	10YR	4	4
			20	5G	3	2																		
SP06 (38.926357, -76.479844)																								
Oase1	15																							
Oase2	28																							
Ase	38																							
ABse	48																							
Bse	56																							
T01P01 (38.930749, -76.483976)																								
Ase	44	C		10Y	3	1	L/SIL					VF	Y	ST	PC	SL	shell	1						
Cseg1	79	C		5GY	2.5	1	L					VF	Y	ST	HS	SL								
Cseg2	124	G		5GY/10GY	3	1	L					MF	Y	SL			shell	1						
Cseg3	156			10GY	3	1	L					MF	Y	SL			shell	5						
T01P02 (38.926678, -76. 487966)																								
Ase	20	C		10Y	2.5	1	LS					NF	Y	ST										
Cseg	40	C		5GY	2.5	1	LS/SL					NF	Y	ST										
2BCb	56	C		10YR	4	3	LS					NF	N	NE										
2CBb	78			5Y	5	3	CoSL					NF	N	NE										
T01P03 (38.925606, -76.488580)																								
Ase	18	C		5GY	2.5	1	L					MF	Y	ST	PC	SL	shell	2						
Cseg1	43	G		5GY	4	1	L					SF	Y	ST	PC	SL	shell	12						
Cseg2	56			5GY	4	1	L					SF	Y	ST	PC	SL	shell	2						

T01P04 (38.916252, -76.496852)																								
Ase	10	C		10GY	2.5	1	L	SICL	12.9	51	36.1	MF	Y	SL										
Cseg1	39	C		10Y	3	1	SL	L	29.9	48.9	21.2	MF	Y	ST										
Cseg2	66	C		5GY	3	1	SL	L	32.8	46.2	21	MF	Y	ST										
Cseg3	112	G		10GY	3	1	SL	L	42.7	39.6	17.6	MF	Y	SL										
Cseg4	142			5GY	3	1	SL	L	41.6	40.3	18.1	SF	Y	SL										
T01P05 (38.913362, -76.502949)																								
Ase	4	C		10Y	2.5	1	L/SL					MF	Y	ST			shell	20						
ACg	30	C		5GY	4	1	SL					MF	N	SL			shell	70						
Cg1	47	G		5GY	3	1	LS/SL					MF	N	VS			shell	2						
Cg2	78	C		10Y/5GY	3	1	LS					NF	N	VS			shell	1						
2Btb	99	C		5Y	6	2 or 3	CL					NF	N	VS										
2BCb	121	C	matrix	10YR	4	4	(Co)LS					NF	N	VS					concentration		P	5YR	3	4
			15	5Y	5	3													concentration		P	5YR	5	8
2CBgb1	140	G		5Y	5	2	LS					NF	N	SL					concentration		D	7.5YR	4	6
2CBgb2	164	C		5Y	5	2	LS					NF	N	VS										
2CBgb3	181			5Y	4 or 5	2	LS					NF	N	NE										
T01P06 (38.911415, -76.504769)																								
Aseg	19	C		10Y	4	1	S	S	90.2	2.6	7.2	NF	N	SL	PC	SL								
Cseg1	32	A		5Y	4	2	LS	SL	78	5.5	16.6	NF	N	SL	PC	SL			depletion	2	D	5BG	4	1
Cseg2	46	C		10Y	3	1	S	S	92	2.8	5.3	NF	N	SL	PC	SL								
Cseg3	62	C		5Y	4	2	LS	SL	76.9	5.4	17.7	NF	N	SL	PC	VS			depletion	5	D	5BG	4	1
2Cseb	71	C		2.5Y	5	4	SCL	SCL	60.6	7.6	31.8	NF	N	SL					concentration	10	D	10YR	4	6
																			depletion	20	P	5BG	4	1
2Csegb	83	A		10Y	3	2	S	SCL	66.1	7.3	26.6	NF	N	SL										
2C'seb	97			10YR	5	6	fSCL	SCL	57.4	13.2	29.4	NF	N	SL					concentration	20	P	5YR	2	1
																			depletion	20	P	10BG	4	1
T01P07 (38.910324, -76.506008)																								

Aseg	6	C		10Y	4	2	fSL					NF	Y	ST										
Ase	21	C		5GY	2.5	1	fSL					NF	Y	ST	HS	SL								
Cseg1	57	G		10GY	2.5	1	L					SF	Y	ST			root hairs	2						
Cseg2	98	C		5GY	4	1	L					SF	Y	ST										
Agb	122	C		5GY	3	1	SL					NF	N	SL			shell	15						
2Btgb	139	C		10Y	5	2	SCL					NF	Y	ST			shell	1	concentration	2	P	7.5YR	4	6
2Cg1	143	C		10Y	3 or 4	1	LS					NF	N	SL			shell	1						
2Cg2	157			5GY	3	1	L					SF	Y	SL										
T01P08 (38.908288, -76.507668)																								
Aseg	9	C		5GY	4	1	L					VF	Y	SL										
Cseg1	59	C		10Y	4	1	SIL					VF	Y	ST			shell	2						
Cseg2	105	D		5GY	4	1	SIL					MF	Y	ST			shell	1						
Cseg3	155	D		5GY	4	1	SIL					MF	N?	ST										
Cseg4	200			10GY	4	1	SIL					MF	N?	ST			shell	trace						
T01P09 (38.906130, -76.509025)																								
A	18	C		10Y	2.5	1	LS					NF	N	SL			shell	50						
2Btsegb1	49	G		5G	4	2	CL/fSCL					NF	Y	ST			woody debris	1	concentration	10	P	10YR	4	6
2Btsegb2	71	C		5GY	4	1	SL/SCL					NF	Y	ST										
2BCsegb	97			5Y	4	2	SL					NF	Y	ST										
T01P10 (38.905114, -76.508546)																								
Ase	32	C		10Y	3	1	SL	S	91.1	2.3	6.6	NF	Y	SL			shell	8						
2Btseb	45	C	matrix	10YR	3	2	SCL	SCL	66	3.9	30.1	NF	Y	ST			woody debris	trace						
			20	5G	3	2																		
2Btsegb	83		matrix	5G	3	2	SCL/CL	SC	57.8	5.2	37	NF	Y	ST/VE			woody debris	trace	concentration	2	D	10YR	6	6
			25	10YR	4	3																		
T01P11 (38.903625, -76.509095)																								
Ase1	4	C		10GY	2.5	1	L	CL	28.2	32.5	39.3	MF	Y	ST	HS	SL	Shell	2						
Ase2	22	C		10Y	3	1	L	CL	31.5	38.8	29.7	MF	Y	ST	PC	SL	shell	2						

Cseg	56	G		10Y	3	1	L	fSL	59.3	22.9	17.7	SF	Y	ST										
2Btsegb	106	C		5G	4	2	CL	C	34.1	9.8	56.1	SF	N	ST										
2BCsegb	165			5Y	3	2	SL	SC	49.7	8.7	41.6	NF	Y	ST/VE					concentration	10	D	10YR	4	4
																			depletion	20	D	5G	4	2
T01P12 (38.902800, -76.510040)																								
A	21	A		10Y	2.5	1	S	LS	81.7	7.4	10.9	NF	N	VS	PC	SL	shell	2						
2Btsegb1	41	C		5GY	4	1	SL	SCL	69.4	8.6	22	MF	Y	ST			organic fragments	5	concentration	2		10YR	6	6
2Btsegb2	55	C		10GY	4	1	CL	SC	48.8	6.1	45.1	SF	N	VE			organic fragments	2	concentration	1		10YR	6	6
2Btsegb3	91	G		5G	4	1	SCL	SCL	67.6	2.6	29.7	NF	N	VE					concentration	20		7.5YR	4	6
2CBsegb1	114	C		10GY	3	1	LS	SL	77.9	2.6	19.5	NF	N	VE					depletion	10		10GY	3	1
2CBsegb2	135			10YR	4	2	LS	LS	88.4	1	10.5	NF	N	ST										
T02P01 (38.930522, -76.526256)																								
Ase	18	C		5GY	2.5	1	LS/SL					NF	Y	SL										
Cseg1	35	C		5GY	2.5	1	SL					NF	Y	SL	PC	SL	shell	8						
																	woody debris	1						
Cseg2	50			10Y	3	1	L					SF	Y	SL	HS	SL	shell	1						
Cseg3	70			N	2.5	0	SIL					MF	Y	SL			woody debris	1						
Cseg4	92			5GY	4	1	SIL					MF	Y	SL										
T02P02 (38.932200, -76.524706)																								
Ag	8	C		2.5Y	5	2	S/LS	S	95.1	1.5	3.4	NF	N	VS										
Cg1	54	G		5GY	4	1	LS	S	89.1	5.7	5.2	NF	N	VS			shell	5						
Cg2	69	C		5GY	4	1	SL/LS	LfS	83.5	9.2	7.3	NF	N	VS			gravel	5						
Cg3	95	C		5GY/10GY	4	1	LS	S	88.8	5.7	5.5	NF	N	VS			gravel	1						
Cg4	138	C		5GY	4	1	L/SL	fSL	66.9	22.6	10.4	NF	N	VS			shell	5						
Cg5	158			5GY	3	1	SL	LS	83	11.7	5.3	NF	N	VS			shell	10						
T02P03 (38.932790, -76.523547)																								
Aseg	20	C		10Y	4	1	S					NF	N	ST			shell	10						

AC	98	C		5GY	3	1	S					NF	N	NE			shell	70						
Cseg1	148			5GY	3	1	SL					NF	N	NE	HS	MO	shell	5						
Cseg2	198			10GY	4	1	SL					NF	N	NE	HS	MO	shell	5						
																	woody debris	1						
Cseg3	248			5GY	4	1	SL/SCL					NF	N	NE	HS	MO	woody debris	1						
Cseg4	268			5GY	4 or 3	1	SL/SCL					NF	N	NE	HS	MO								
T02P04 (38.933193, -76.522226)																								
Ase1	11	C		10GY	2.5	1	SIL					VF	Y	ST	PC	SL								
Ase2	38	C		10GY	2.5	1	SCL	SICL	18	52.9	29.1	VF	Y	VE	PC	SL								
Cseg1	88	D		5GY	4	1	SCL	CL	27.7	40.2	32.1	MF	Y	VE	PC	SL								
Cseg2	113	C		10GY	3	1	SCL	L	36.9	37	26.1	MF	Y	ST	PC	SL								
Cseg3	163	D		10GY	4	1	SCL	L	43.2	34.1	22.7	MF	Y	SL	PC	SL								
Cseg4	200			10GY	3	1	SC	L	36.4	37.8	25.8	MF	Y	SL	PC	SL								
T02P05 (38.934687, -76.520528)																								
Ase1	23	C		N	2.5	0	L/SIL					VF	Y	SL	HS	SL	shell	2						
Ase2	58	C		N	2.5	0	L/SIL					VF	Y	SL			shell	1						
Cseg1	89	C		10GY	2.5	1	L/SICL					MF	Y	SL										
Cseg2	111	C		10GY	2.5	1	L/SICL					SF	Y	SL										
Cseg3	141			5G	3	1	CL					MF	Y	SL			shell	2						
T02P06 (38.935628, -76.519072)																								
Ase1	8	C		10Y	2.5	1	SL					MF	Y	SL			shell	5						
Ase2	21	C		5GY	2.5	1	SL					MF	Y	SL			shell	5						
Cseg1	40	C		5GY	3 or 4	1	SL					MF	Y	SL			shell	5						
Cseg2	49	C		10GY	3 or 4	1	LS					SF	Y	SL			shell	20						
Cg	71			5GY	4	1	S					NF	Y	NE			shell	5						
T02P07 (38.93756976, -76.51737875)																								
Ase	18	C		10Y	3	1	S/LS	S	95.8	1	3.2	NF	Y	SL										
AC	37	C		5GY	3	1	S	S	94	1.8	4.2	NF	N	SL			shell	50						

Cg1	71	C		5GY	3	1	S/LS	S	90.8	3.6	5.6	NF	N	NE										
Cg2	113	C		5GY	3 or 4	1	CoS	S	90.4	3.9	5.7	NF	N	VS			shell	5						
AC'b	147	C		5GY	3	1	(Co)SL	SL	80.1	7.1	12.8	NF	N	NE			shell	40						
2Ab	160			7.5YR/5YR	2.5	1	L	LS	84.1	4.9	11	NF	N	NE			root fragments	10						
2Egb	168	G		10Y	4	1	LS	S	91.2	4.5	4.3	NF	N	NE										
2CBb1	219	C		10YR	4	3	S	S	93.3	2.9	3.9	NF	Y	VS										
2CBb2	244			10YR	4	4	S	S	92.6	3.9	3.6	SF	Y	VS										
T02P08 (38.93877952, -76.5173495)																								
Ase	16	A		10Y	3	1	S	LS	89.1	2.6	8.3	NF	Y	SL			shell	trace						
2BCb1	32	C		10YR	4	4	SL	SL	78.8	4.6	16.5	NF	N	NE					concentration	6	P	7.5YR	6	8
2BCb2	55	C		10YR	5	3	LS	SL	82.2	4	13.9	NF	N	NE					concentration	6	P	5YR	5	6
2CBb	82			10YR	4	2	LS	SL	80.7	4.9	14.3	NF	N	NE										
T03P01 (38.93395968, -76.53939508)																								
Ase	10	C		5GY	2.5	1	S					NF	Y	SL										
Cseg	25	C		5GY	4 or 3	1	S					NF	N	SL										
2BCsegb	42	C	matrix	10Y	4	2	SL/SCL					NF	N	VE					concentration		P	7.5YR	5	6
			20	5G	3	2																		
2BCseb	59			5Y	4	3	SL/SCL					NF	N	VE					concentration		P	7.5YR	5	8
																			depletion	15		5G	4	1
T03P02 (38.93390629, -76.53906098)																								
Ase1	15	C		10Y	3	1	LS					NF	Y	SL	HS	SL								
Ase2	39	C		10Y	3	1	LS					NF	Y	SL	HS	ST	shell	20						
Cseg1	74	C		10Y	2.5	1	LS					NF	Y	SL	PC	SL								
2Cseg2	84	A		5GY	5	2	SL/SCL					NF	Y	SL					concentration	2	D			
2Cseg3	117	C		5GY	4	2	SCL					NF	Y	ST			gravel	trace	concentration	2	D			
2Cseg4	137			10Y	4	2	SL/SCL					NF	Y	ST					concentration	5	P	10YR	4	6
				5G	4	2																		
T03P03 (38.93374116, -76.53778751)																								

A	8	C		10Y	2.5	1	LS					NF	Y	SL										
ACg	27	C		5GY	4	1	LCoS					NF	N	SL			shell	60						
																	gravel	2						
2BCb1	48	C		10Y	3	2	LCoS					NF	N	SL					concentration		D	7.5YR	3	2
2BCb2	61	A		5Y	4	3	LCoS/CoSL					NF	N	SL					concentration		D	10YR	4 or 5	4
2Cg	81	A		5Y	4	2	LS					NF	Y	VS			gravel	10						
2C	110			2.5Y	4	3	LS					NF	N	NE					concentration	20		7.5YR	4	4
T03P04 (38.93197677, -76.53777779)																								
Aseg	10	C		10Y	4	1	S/LS					NF	Y	ST			shell	1						
Ase	24	C		10Y	2.5	1	S/LS					NF	Y	ST			shell	20						
2Btgb1	38	C		2.5Y	5	2	S/LS					NF	N	SL			gravel	5						
2Btgb2	65	C		10Y	5	2	S/LS					NF	N	SL										
2Btb1	79	C		5Y	5	3	LS					NF	N	NE										
2Btb2	105	C		2.5Y	6	4	CoSL/CoSCL					NF	N	NE			gravel	10	concentration			5YR	6	3
																	cobbles	1						
2BCtb	119	C		5Y	5	3	SL/LS					NF	N	NE										
2BCtgb	147			10Y	5	2	SL					NF	N	NE					concentration	5	P	5YR	3	3
T03P05 (38.93031179, -76.53731788)																								
Ase1	14	G		10Y	2.5	1	SIL					VF	Y	ST	PC	SL								
Ase2	45	C		10Y	2.5	1	SIL	SIL	27	54.4	18.6	VF	Y	ST	PC	SL								
Cseg1	90	C		5GY	3	1	SICL	CL	32.6	35.4	32	MF	Y	ST	PC	SL								
Cseg2	151	C		10GY	3	1	SICL	SIC	18.5	40.6	40.9	MF	Y	ST	PC	SL	shell	1						
Cseg3	200			10GY	3	1	SIC	L	47.6	28.3	24.1		Y	SL	PC	SL	shell	1						
T03P06 (38.92868805, -76.53544368)																								
Ase1	6	C		10Y	2.5	1	SL					SF	N	ST	rotting oyster									
Ase2	19	C		5GY	2.5	1	SL					SF	N	SL	rotting oyster		shell	2						
ACg	44	C		5GY	3	1	S/LS					NF	N	SL			shell	60						
2Bgb1	65	C		5GY	4	2	SL/LS					NF	N	VS			gravel	trace						

2Bgb2	104			10Y	4	2	LS					NF	N	NE					concentration	5	D	10YR	4	6
T03P07 (38.9281283, -76.53500279)																								
Ase1	22	C		5GY	3	1	LS	S	95.6	1.1	3.3	NF	Y	ST										
Ase2	43	C		5GY	2.5	1	LS/SL	fSL	81.2	4.5	14.2	NF	N	ST										
Ase3	57	C		10GY	2.5	1	SL	LS	88.5	3.6	7.9	NF	N	SL			shell	30						
																	gravel	1						
2BAb	78	C		5GY	3	1	SL	LS	83.3	8.8	7.9	NF	N	SL			gravel	1						
																	woody debris	2						
2Btgb	103	C		10GY	3	1	SL	fSL	71.9	12.1	15.9	NF	N	SL			woody debris	2						
2BCgb1	116	C		10Y	5	2	LS	S	93.6	2	4.4	NF	N	NE										
2BCgb2	130	C		5Y	5	2	LS	S	96.6	1.9	1.5	NF	N	NE										
2C	159			2.5Y	5	3	LS	S	94.7	2	3.3	NF	N	NE					concentration	20	P	5YR	5	6
																			concentration	10	P	5YR	5	8
T04P01 (38.94637227, -76.54733651)																								
Ase	24	C		10Y	4	1	S	fS	97.5	0.2	2.3	NF	N	SL			shell	1						
Cseg1	48	G		5GY	4	1	S	fS	92.6	3.1	4.4	NF	N	SL										
Cseg2	68	C		5GY	3	1	SL	LfS	86.6	5.3	8.1	NF	Y	SL										
Cseg3	82	C		5GY	2.5	1	SL	LfS	85.7	7.1	7.2	NF	Y	SL										
Cseg4	128	G		N	3	0	fSL	fSL	77.6	12.9	9.4	NF	Y	SL			shell	trace						
			or	5GY	3	1																		
Cseg5	164	C	matrix	5GY	3	1	fSCL	fSL	58.1	27.5	14.4	SF	Y	SL										
			30	N	2.5	0																		
Cseg6	176	C		N	2.5	0	SIL	L	44.4	40.9	14.7	SF	Y	SL										
Cseg7	253	G		5GY	3	1	L	L	50.4	38.1	11.5	SF	Y	SL										
Cseg8	282	C		5GY	3	1	fSL	fSL	69.2	23.1	7.8	SF	Y	SL			shell	5						
Cseg9	300			10Y/5GY	3	1	LS	fS	89.9	6.4	3.7	NF	N	SL										
T04P02 (38.94766903, -76.54737549)																								
ACg	37	C		5GY	4	1	LS					NF	N	VS			shell	50						

Cg1	97	G		10Y	3	1	LS					NF	N	VS	HS	SL	shell	1						
Cg2	141	G		5GY	3	1	LS					NF	N	VS	NS	VS	shell	1						
Cg3	171			5GY	3	1	LS					NF	N	VS			shell	5						
T04P03 (38.949407, -76.546309)																								
Ase1	30	C		N	2.5	0	SIL					VF	Y	SL	HS	SL								
Ase2	50	C		N	2.5	0	SIL					VF	Y	SL										
Ase3	70	C		N	2.5	0	L					VF	Y	SL			shell	2						
Cseg1	103	C		N	2.5	0	SIL					VF	Y	SL										
Cseg2	127	C		10Y	2.5	1	SIL/L					VF	Y	SL										
Cseg3	155	C		10Y	2.5	1	SIL/L					MF	Y	SL										
Cseg4	173			10Y or 5GY	3	1	L					SF	Y	SL										
T04P04 (38.95012845, -76.5464736)																								
Aseg	13	C		2.5Y	4	2	S					NF	N	ST			shell	20						
Cseg1	51	C		10Y	2.5	1	S					NF	Y	ST	PC	SL	shell	10						
Cseg2	66			10Y	2.5	1	S					NF	Y	SL	PC	SL								
T04P05 (38.95067906, -76.54585325)																								
Ase	14	C		5Y	3	2	LS					NF	Y	ST			shell	1						
Cseg	48	C		10Y	4	2	LS					NF	Y	SL			shell	1						
ACg	96	C		10Y	3	1	LS					NF	Y	SL			shell	50						
Cg	140			10Y	3	2	LS					NF	Y	VS			shell	1						
																	woody debris	2						
T05P01 (38.93673814, -76.5851679)																								
Ase1	15	C		10GY	2.5	1	L					VF	Y	SL	PC	SL	organic fragments	1						
Ase2	41	C		5GY	3	1	L					VF	Y	SL	PC	SL	organic fragments	6						
																	shell	1						
Cseg1	88	G		5BG	2.5	1	L					MF	Y	ST	PC	SL	shell	2						
																	organic fragments	2						
Cseg2	138	D		10GY	2.5	1	L					VF	Y	SL	PC	SL	shell	1						

Cseg3	181	G		5G	3	1	SIL					MF	Y	ST	PC	SL								
Cseg4	200			10G	2.5	1	SIL					MF	Y	ST	PC	SL								
T05P02 (38.93747488, -76.58133837)																								
Ase1	17	C		10Y	2.5	1	L					VF	Y	SL	PC	SL	shell	1						
Ase2	42	C		5GY	3	1	L					VF	Y	SL	PC	SL	shell	1						
Cseg1	85	G		10GY	2.5	1	L					MF	Y	ST	PC	SL	shell	3						
Cseg2	114	G		5GY	2.5	1	SIL					MF	Y	ST	PC	SL	shell	1						
Cseg3	162	D		10GY	2.5	1	SIL					VF	Y	SL	PC	SL	shell	1						
Cseg4	200			10GY	2.5	1	SIL					MF	Y	ST	PC	SL								
T05P03 (38.94076335, -76.57793582)																								
Ase1	10	G		5GY	2.5	1	L					VF	Y	SL	PC	SL								
Ase2	37	C		10Y	2.5	1	SIL	SIL	13.1	71.2	15.7	VF	Y	SL	HS	MO	shell	5						
Cseg1	90	C		N	2.5	0	SIL	CL	42.3	28.9	28.8	VF	Y	ST	PC	SL	shell	1						
Cseg2	128	C		N	2.5	0	SIL	SICL	18.4	50.1	31.5	VF	Y	ST	PC	SL	shell	1						
Cseg3	178	D		10GY	2.5	1	SICL	C	22.9	33.8	43.4	MF	Y	ST	PC	SL	shell	1						
Cseg4	200			10GY	2.5	1	SICL	SL	64.3	20.2	15.5	MF	Y	ST	PC	SL	shell	1						
T05P04 (38.94363843, -76.57632482)																								
Ase1	16			10Y	2.5	1	L					VF	Y	SL	HS	SL								
Ase2	36			10Y	2.5	1	L					VF	Y	SL	PC	SL								
Cseg1	80			5GY	2.5	1	L					MF	Y	ST	PC	SL	fiber?	1						
																	twig	1						
																	shell	1						
Cseg2	113			10GY	2.5	1	SL					SF	Y	SL	PC	SL								
T05P05 (38.94935858, -76.57245699)																								
Ase	19	C		10Y	2.5	1	L					VF	Y	SL	HS	SL								
Aseg	48	C		5GY	3	1	L					VF	Y	SL	HS	SL								
Cseg	71	A		5GY	3	1	L					VF	Y	SL	PC	SL								
Asegb	98	C		N	2.5	0	L					MF	Y	SL	PC	SL	shell	1						

C'seg1	143	C		10GY	2.5	1	L					MF	Y	SL	PC	SL	shell	1						
C'seg2	188	G		5GY	2.5	1	SICL					MF	N?	SL	PC	SL	shell	1						
C'seg3	200			5GY	3	1	SICL					MF	N?	SL			shell	1						
T05P06 (38.9526447, -76.57089008)																								
Aseg	7	C		10Y	3	1	LS					NF	Y	ST	PC	SL								
Cseg	16	C		5GY	4	1	SL					NF	N	SL	PC	SL	shell	2						
ACg	30	C		5GY	3	1	LS					NF	N	VS	PC	SL	shell	40						
Cg1	52	C		5GY	3	1	LS					NF	N	VS	PC	SL	shell	1						
Cg2	63			5GY	3	1	LCoS					NF	N	VS										
T05P07 (38.95320302, -76.57117967)																								
Ase	4	C		N	2.5	0	S/LS					NF	Y	SL			woody debris	5						
Cg1	32	G		5Y	4	1	S/LS					NF	N	VS			gravel	5						
																	woody debris	1						
Cg2	68	G		5Y	5	1	S					NF	N	NE			shell	5						
Cg3	105	C		5GY	4	1	LS					NF	N	NE			woody debris	1						
Agb	116	C		10Y/5GY	2.5	1	SL					NF	N	NE			shell	1						
C'g1	135	G		5GY	2.5	1	SL					NF	N	SL			woody debris	1						
C'g2	161	C		10Y	2.5	1	SL					NF	N	SL			woody debris	2						
C'g3	186	C		10Y	2.5	1	LS						N	SL			shell	10						
2BCgb	209	C		10GY	5	1	CoSC					NF	Y	SL			gravel?	40	concentration			10YR	3	4
2CBgb	232			5GY	6	1	C/CL					NF	Y	SL					concentration			10YR	6	8
T05P08 (38.95373602, -76.57078003)																								
Ase	3	C		10Y	2.5	1	L	LfS	85.2	4	10.8	NF	Y	ST	PC	SL								
Cseg1	26	C		5GY	4	1	L	fSL	74.9	6.8	18.3	NF	Y	ST	PC	SL	shell	1						
Cseg2	37	C		5GY	2.5	1	SL	S	89.8	2.5	7.7	NF	Y	ST	PC	SL	shell	1						
ACg	61	C		5GY	2.5	1	SL	S	93.3	1.2	5.5	NF	Y	SL	PC	SL	shell	40						
C'seg1	83	C		10Y	3	1	LCoS	S	96.1	1.8	2.1	NF	N	SL	PC	SL								
C'seg2	135			5GY	2.5	1	LS	S	91	4.1	4.9	NF	N	SL	PC	SL								

T05P09 (38.95511133, -76.57043595)																								
Ase	21	C		N	2.5	0	L	L	33.3	46.4	20.3	VF	Y	SL	HS	MO	fiber	1						
Cseg1	54	C		10GY	2.5	1	L	SIL	24.2	54	21.9	VF	Y	SL	PC	SL	shell	1						
Cseg2	94	C		10GY	2.5	1	L	SCL	51.1	23.5	25.4	VF	Y	SL	PC	SL	shell	1						
Cseg3	145	G		5GY	2.5	1	CL	SCL	51.8	26.5	21.8	MF	Y	SL	PC	SL	shell	1						
Cseg4	176	D		5GY	2.5	1	L	SL	58.7	22.4	18.9	MF	Y	SL	PC	SL	shell	2						
Cseg5	200			10GY	3	1	L	SL	61.9	21.5	16.7	SF	Y	SL	PC	SL	shell	1						
T05P10 (38.95707454, -76.56984234)																								
Ase	13	C		N	2.5	0	L	fS	88.8	4.1	7.1	NF	Y	SL	PC	SL								
Aseg	32	C		10Y	3	1	L	LfS	82.6	5.3	12.1	NF	N	SL	PC	SL	shell	2	concentration	5	D	10YR	4	3
Cseg1	59	C		5GY	4	1	LS	S	96.4	1.2	2.4	NF	N	SL	PC	SL								
Cseg2	122	G		10Y	3	1	LS	fS	90.4	3.5	6.1	NF	N	SL										
Cseg3	165			5GY	3	1	LS	S	94.8	1.8	3.4	NF	N	SL										
T05P11 (38.95835211, -76.57097641)																								
Ase	12	C		5GY	2.5	1	S	S	97	1	2	NF	Y	SL	PC	SL								
Cseg1	22	C		10Y	3	1	S	fS	92.7	4.9	2.4	NF	Y	SL	PC	SL	gravel	just one						
Cseg2	40	C		10Y	3	1	SL	fSL	73.6	17.2	9.2	NF	Y	VS	PC	SL								
2Bwb	50	A		10YR	5	3	LS	LfS	85.8	7.1	7.1	NF	N	NE	PC	SL	gravel	3	concentration	3	D	7.5YR	6	6
2BCb	86			5YR	5	6	LS	fSL	75.6	6.2	18.3	NF	N	NE	PC	SL	gravel	1						
T06P01 (38.97468081, -76.57358159)																								
Ase1	9	A		10Y	2.5	1	L					VF	Y	VE	PC	SL	organic fragments	5						
Ase2	38	A		N	2.5	0	L					VF	Y	VE	PC	SL	shell	5						
Ase3	90	C		N	2.5	0	CL					MF	Y	ST	PC	SL	shell	10						
Cseg1	115	C		10Y	2.5	1	SL					VF	Y	ST	PC	SL								
Cseg2	152	A		N	2.5	0	CL					MF	Y	ST	PC	SL								
Cseg3	200			N	2.5	0	CL					MF	Y	ST	PC	SL								
T06P02 (38.97247385, -76.57599349)																								
Ase	20	C		N	2.5	0	L					VF	Y	SL	PC	SL								

Cseg1	38	C		10Y	2.5	1	L					VF	Y	SL	PC	SL	woody debris	1						
Cseg2	50	C		5GY	2.5	1	L					VF	Y	SL	PC	SL	woody debris	1						
Aseb1	84	G		N	2.5	0	SIL					VF	Y	SL	PC	SL	shell	1						
Aseb2	123	G		N	2.5	0	L					MF	Y	SL	PC	SL								
C'seg	176	G		10GY	2.5	1	SIL					MF	Y	SL	PC	SL	shell	trace						
2Cg1	226	G		5Y	2.5	1	SIL					SF	N	VS			shell	1						
																	root hairs	10						
2Cg2	276	G		5Y	2.5	1	SIL					SF	N	VS			root hairs	10						
2Cg3	317			5Y	2.5	1	SIL					SF	N	VS			root hairs	10						
T06P03 (38.96927347, -76.57604009)																								
Ase1	14	G		10GY	2.5	1	L					VF	Y	SL	PC	SL								
Ase2	52	C		10Y	2.5	1	L					VF	Y	SL	PC	SL								
Cseg1	83	C		5GY	2.5	1	L					VF	Y	ST	PC	SL	shell	1						
Cseg2	135	A		10GY	2.5	1	L					VF	Y	ST	PC	SL								
Cseg3	166	C		10GY	2.5	1	SICL					MF	Y	ST	PC	SL								
Cseg4	200			10Y	2.5	1	SICL					MF	N	ST	PC	SL	organic fragments	3						
																	shell	2						
T06P04 (38.96785961, -76.57778042)																								
Ase	22	C		N	2.5	0	L	SIL	17.4	63.8	18.7	VF	Y	SL										
Aseg	46	C		10Y	3	1	L	SIL	10.3	68.7	21	VF	Y	SL										
Aseb	86	C		N	2.5	0	SICL	SIL	13	61.7	25.4	MF	Y	SL			shell	2						
Cseg	122	C		5GY	2.5	1	SICL	SIL	10.7	67.9	21.4	MF	Y	SL										
2Cg1	142	C		10Y	2.5	1	SICL	SIL	19.9	59.4	20.7	SF	N	VS	PC	SL	shell	1						
																	root hairs	10						
2Cg2	185	G		10Y	2.5	1	SICL	SIL	23	51.7	25.2	SF	N	VS	PC	SL	shell	1						
																	root hairs	10						
2Cg3	236			10Y	2.5	1	SICL	SIL	24.1	51.7	24.2	SF	N	VS	PC	SL	root hairs	10						
T06P05 (MAC) (38.96439428, -76.57669656)																								

Ase1	10	C		10GY	2.5	1	SIL					VF	Y	SL	PC	SL								
Ase2	32	C		5GY	2.5	1	SIL					VF	Y	SL	PC	SL								
Ase3	50			N	2.5	0	SIL					VF	Y	SL	PC	MO								
T06P05 (VIB) (38.96439428, -76.57669656)																								
Ase1	6	C		N	2.5	0	L					VF	Y	SL	HS	SL								
Ase2	25	C		N	2.5	0	L	L	30.5	49.7	19.9	VF	Y	SL	HS	SL								
Ase3	42	C		10Y/5GY	2.5	1	L/SIL	SIL	21.3	59.2	19.5	VF	Y	SL	PC	SL								
Cseg	68	C		5GY	2.5	1	SIL/L	CL	30.1	33.4	36.6	VF	Y	SL	PC	SL								
Aseb	96	C		N	2.5	0	SIL	SICL	13	54.2	32.7	MF	Y	SL	HS	SL								
C'seg	126	C		5GY	3	1	CL/SICL	SIC	12.9	40.5	46.5	SF	Y	SL	PC	SL								
Cg	169			10Y	3	1	SICL	SIL	18.8	61.2	20	SF	N	VS			shell	3						

Appendix B. Particle Size Analysis Data

Pedon	Horizon	Bottom Depth (cm)	% Sand	% Silt	% Clay	Sand Separates					Texture Class
						% vc	% c	% m	% f	% vf	
SP03	Ase	7	83.4	3.9	12.7	1.0	5.1	36.4	37.4	3.4	LS
SP03	2A'se	46	61.8	19.9	18.4	1.0	3.7	23.9	29.4	3.7	SL
SP03	2Eseg	55	69.2	22.7	8.2	0.2	3.7	22.9	38.4	4.0	SL
SP03	2Btseg1	69	56.6	20.0	23.3	0.9	6.3	22.9	22.5	4.1	SCL
SP03	2Btseg2	86	40.9	8.0	51.1	0.5	6.6	16.1	14.6	3.0	C
SP03	2Btseg3	117	52.1	8.4	39.5	0.9	12.3	22.3	14.0	2.5	SC
SP04	Ase	11	70.7	10.7	18.5	1.3	7.1	39.1	18.6	4.7	SL
SP04	ABseg1	21	78.1	13.7	8.3	0.4	4.9	33.2	35.7	3.8	SL
SP04	ABseg2	31	73.9	14.1	12.0	0.5	4.2	33.3	31.5	4.4	SL
SP04	Btg1	50	64.3	13.2	22.5	0.7	4.0	25.9	29.5	4.2	SCL
SP04	Btg2	66	54.9	8.9	36.2	10.6	6.8	16.2	18.1	3.1	SC
SP04	BCt	78	51.6	7.9	40.4	2.8	4.3	20.4	22.7	1.4	SC
SP04	BCtg	116	53.2	7.5	39.3	0.7	5.5	26.4	19.1	1.6	SC
T01P04	Ase	10	12.9	51.0	36.1	0.1	0.1	0.6	0.9	11.1	SICL
T01P04	Cseg1	39	29.9	48.9	21.2	9.3	8.2	5.0	3.7	3.8	L
T01P04	Cseg2	66	32.8	46.2	21.0	12.3	8.7	4.9	5.5	1.2	L
T01P04	Cseg3	112	42.7	39.6	17.6	19.1	10.1	6.1	5.9	1.5	L
T01P04	Cseg4	142	41.6	40.3	18.1	13.7	11.5	6.6	8.2	1.7	L
T01P06	Aseg	19	90.2	2.6	7.2	0.5	11.7	63.5	13.5	1.0	S
T01P06	Cseg1	32	78.0	5.5	16.6	0.2	14.3	39.3	21.7	2.4	SL
T01P06	Cseg2	46	92.0	2.8	5.3	0.3	11.5	50.8	27.8	1.5	S
T01P06	Cseg3	62	76.9	5.4	17.7	0.4	14.6	34.8	25.1	2.0	SL
T01P06	2Cseb	71	60.6	7.6	31.8	0.2	7.0	24.5	25.3	3.6	SCL
T01P06	2Csegb	83	66.1	7.3	26.6	0.5	5.0	24.8	33.1	2.7	SCL
T01P06	2C'seb	97	57.4	13.2	29.4	0.6	3.1	9.7	35.3	8.6	SCL
T01P10	Ase	32	91.1	2.3	6.6	0.2	4.5	41.3	42.9	2.2	S
T01P10	2Btseb	45	66.0	3.9	30.1	0.2	6.4	32.2	25.5	1.6	SCL
T01P10	2Btsegb	83	57.8	5.2	37.0	0.0	3.5	20.3	31.9	2.2	SC
T01P11	Ase1	4	28.2	32.5	39.3	0.0	0.5	2.7	11.3	13.7	CL
T01P11	Ase2	22	31.5	38.8	29.7	0.3	0.9	4.9	14.9	10.5	CL
T01P11	Cseg	56	59.3	22.9	17.7	0.2	5.1	22.7	27.7	3.6	SL
T01P11	2Btsegb	106	34.1	9.8	56.1	0.1	4.0	10.7	16.8	2.4	C
T01P11	2BCsegb	165	49.7	8.7	41.6	0.1	5.8	19.6	22.1	2.1	SC
T01P12	A	21	81.7	7.4	10.9	0.3	13.0	45.2	20.9	2.3	LS
T01P12	2Btsegb1	41	69.4	8.6	22.0	0.0	12.8	37.3	17.4	2.0	SCL
T01P12	2Btsegb2	55	48.8	6.1	45.1	0.4	7.7	23.7	15.5	1.6	SC

T01P12	2Btsegb3	91	67.6	2.6	29.7	0.1	11.9	39.1	15.0	1.6	SCL
T01P12	2CBsegb1	114	77.9	2.6	19.5	0.5	10.6	41.7	23.1	2.0	SL
T01P12	2CBsegb2	135	88.4	1.0	10.5	0.1	15.7	53.9	17.5	1.2	LS
T02P02	Ag	8	95.1	1.5	3.4	0.2	5.8	47.9	39.3	1.8	S
T02P02	Cg1	54	89.1	5.7	5.2	0.8	3.1	30.8	47.6	6.7	S
T02P02	Cg2	69	83.5	9.2	7.3	0.9	5.4	17.8	52.3	7.2	LS
T02P02	Cg3	95	88.8	5.7	5.5	0.4	7.4	43.6	30.7	6.6	S
T02P02	Cg4	138	66.9	22.6	10.4	0.3	2.1	8.7	46.7	9.1	SL
T02P02	Cg5	158	83.0	11.7	5.3	0.7	4.9	31.9	36.5	9.0	LS
T02P04	Ase2	38	18.0	52.9	29.1	0.7	2.2	2.5	8.3	4.3	SICL
T02P04	Cseg1	88	27.7	40.2	32.1	0.3	6.1	9.2	8.0	4.1	CL
T02P04	Cseg2	113	36.9	37.0	26.1	4.6	12.0	8.4	8.9	3.0	L
T02P04	Cseg3	163	43.2	34.1	22.7	5.8	11.9	10.1	10.4	5.0	L
T02P04	Cseg4	200	36.4	37.8	25.8	0.9	7.5	11.3	14.5	2.2	L
T02P07	Ase	18	95.8	1.0	3.2	0.1	0.9	60.1	34.0	0.7	S
T02P07	AC	37	80.1	7.1	12.8	1.6	16.9	45.6	14.0	2.1	SL
T02P07	Cg1	71	90.8	3.6	5.6	0.2	5.1	35.1	48.9	1.5	S
T02P07	Cg2	113	90.4	3.9	5.7	5.0	25.4	51.1	7.7	1.3	S
T02P07	2Ab	160	84.1	4.9	11.0	1.0	14.3	49.5	17.5	1.8	LS
T02P07	2Egb	168	91.2	4.5	4.3	1.7	17.8	52.2	17.9	1.5	S
T02P07	2CBb1	219	93.3	2.9	3.9	1.3	17.6	58.7	14.1	1.5	S
T02P07	2CBb2	244	92.6	3.9	3.6	2.4	14.5	53.6	20.3	1.8	S
T02P08	Ase	16	89.1	2.6	8.3	0.8	8.5	66.2	12.9	0.7	LS
T02P08	2BC1	32	78.8	4.6	16.5	1.8	21.3	46.7	7.6	1.4	SL
T02P08	2BC2	55	82.2	4.0	13.9	1.4	14.6	51.8	13.0	1.3	SL
T02P08	2CBg	82	80.7	4.9	14.3	0.4	12.8	57.8	8.7	1.0	SL
T03P05	Ase2	45	27.0	54.4	18.6	0.2	3.4	6.0	13.9	3.5	SIL
T03P05	Cseg1	90	32.6	35.4	32.0	1.1	8.4	9.3	10.7	3.0	CL
T03P05	Cseg2	151	18.5	40.6	40.9	0.1	2.5	5.4	9.1	1.5	SIC
T03P05	Cseg3	200	47.6	28.3	24.1	2.1	12.8	13.4	17.7	1.5	L
T03P07	Ase1	22	95.6	1.1	3.3	0.0	1.5	70.6	22.1	1.4	S
T03P07	Ase2	43	81.2	4.5	14.2	0.1	1.3	17.9	60.2	1.7	SL
T03P07	Ase3	57	88.5	3.6	7.9	2.7	5.3	30.0	44.9	5.5	LS
T03P07	2BAb	78	83.3	8.8	7.9	3.4	5.4	31.0	39.8	3.8	LS
T03P07	2Btgb	103	71.9	12.1	15.9	0.6	3.6	16.9	48.0	2.9	SL
T03P07	2BCgb1	116	93.6	2.0	4.4	1.4	8.3	61.5	20.6	1.7	S
T03P07	2BCgb2	130	96.6	1.9	1.5	4.9	9.9	47.1	32.7	2.0	S
T03P07	2C	159	94.7	2.0	3.3	2.0	13.4	58.3	20.0	1.0	S
T04P01	Ase	24	97.5	0.2	2.3	0.8	4.8	34.8	53.8	3.3	S
T04P01	Cseg1	48	92.6	3.1	4.4	0.4	4.8	20.2	64.0	3.1	S

T04P01	Cseg2	68	86.6	5.3	8.1	0.1	2.1	4.5	71.9	8.0	LS
T04P01	Cseg3	82	85.7	7.1	7.2	0.1	2.0	6.1	69.5	8.0	LS
T04P01	Cseg4	128	77.6	12.9	9.4	0.0	0.3	1.8	64.1	11.4	SL
T04P01	Cseg5	164	58.1	27.5	14.4	0.0	0.3	1.8	44.5	11.5	SL
T04P01	Cseg6	176	44.4	40.9	14.7	0.1	1.1	1.9	22.0	19.2	L
T04P01	Cseg7	253	50.4	38.1	11.5	1.5	2.4	4.8	29.0	12.7	L
T04P01	Cseg8	282	69.2	23.1	7.8	0.5	3.2	9.9	38.0	17.5	SL
T04P01	Cseg9	300	89.9	6.4	3.7	1.0	6.1	23.6	52.5	6.7	S
T05P03	Ase2	37	13.1	71.2	15.7	0.4	3.0	3.6	3.2	2.9	SIL
T05P03	Cseg1	90	42.3	28.9	28.8	7.3	10.8	10.7	10.7	2.7	CL
T05P03	Cseg2	128	18.4	50.1	31.5	0.1	0.4	1.1	7.0	9.8	SICL
T05P03	Cseg3	178	22.9	33.8	43.4	0.8	4.7	7.2	8.0	2.1	C
T05P03	Cseg4	200	64.3	20.2	15.5	2.8	20.5	21.6	12.8	6.5	SL
T05P08	Ase	3	85.2	4.0	10.8	0.2	2.8	12.5	51.6	18.1	LS
T05P08	Cseg1	26	74.9	6.8	18.3	0.2	1.9	14.6	44.3	14.0	SL
T05P08	Cseg2	37	89.8	2.5	7.7	0.1	3.1	24.6	45.0	17.0	S
T05P08	ACg	61	93.3	1.2	5.5	0.5	6.1	45.4	37.8	3.5	S
T05P08	C'seg1	83	96.1	1.8	2.1	0.5	7.3	60.5	25.9	1.9	S
T05P08	C'seg2	135	91.0	4.1	4.9	0.2	8.0	55.8	23.1	3.8	S
T05P09	Ase	21	33.3	46.4	20.3	1.0	5.7	5.0	12.8	8.6	L
T05P09	Cseg1	54	24.2	54.0	21.9	0.1	2.2	6.2	11.4	4.2	SIL
T05P09	Cseg2	94	51.1	23.5	25.4	8.4	12.1	13.7	14.3	2.5	SCL
T05P09	Cseg3	145	51.8	26.5	21.8	3.6	5.2	19.5	19.0	4.5	SCL
T05P09	Cseg4	176	58.7	22.4	18.9	4.2	18.1	14.4	18.6	3.4	SL
T05P09	Cseg5	200	61.9	21.5	16.7	5.5	18.8	16.6	17.9	3.1	SL
T05P10	Ase	13	88.8	4.1	7.1	0.0	0.4	5.4	70.2	12.8	S
T05P10	Aseg	32	82.6	5.3	12.1	0.0	0.6	10.0	67.1	4.8	LS
T05P10	Cseg1	59	96.4	1.2	2.4	0.0	1.6	46.6	46.7	1.5	S
T05P10	Cseg2	122	90.4	3.5	6.1	0.0	2.0	17.3	68.9	2.2	S
T05P10	Cseg3	165	94.8	1.8	3.4	0.2	2.4	44.9	44.8	2.4	S
T05P11	Ase	12	97.0	1.0	2.0	1.1	5.0	27.4	58.3	5.1	S
T05P11	Cseg1	22	92.7	4.9	2.4	0.6	1.5	5.9	72.6	12.0	S
T05P11	Cseg2	40	73.6	17.2	9.2	2.4	3.7	7.8	49.5	10.2	SL
T05P11	2Bwb	50	85.8	7.1	7.1	2.5	3.2	8.3	58.8	12.9	LS
T05P11	2BCb	86	75.6	6.2	18.3	2.6	7.4	32.1	32.0	1.4	SL
T06P04	Ase	22	17.4	63.8	18.7	0.0	1.7	5.2	5.0	5.5	SIL
T06P04	Aseg	46	10.3	68.7	21.0	0.3	1.5	1.3	2.5	4.6	SIL
T06P04	Aseb	86	13.0	61.7	25.4	0.0	0.0	0.0	12.8	0.2	SIL
T06P04	Cseg	122	10.7	67.9	21.4	0.2	0.8	1.4	3.6	4.7	SIL
T06P04	2Cg1	142	19.9	59.4	20.7	0.0	2.0	5.6	8.4	4.0	SIL

T06P04	2Cg2	185	23.0	51.7	25.2	0.0	2.0	5.6	9.3	6.2	SIL
T06P04	2Cg3	236	24.1	51.7	24.2	0.7	3.6	4.9	10.5	4.3	SIL
T06P05	Ase2	25	30.5	49.7	19.9	0.0	1.2	5.6	16.4	7.2	L
T06P05	Ase3	42	21.3	59.2	19.5	0.0	1.7	6.1	7.6	5.9	SIL
T06P05	Cseg	68	30.1	33.4	36.6	1.8	9.6	10.1	6.9	1.6	CL
T06P05	Aseb	96	13.0	54.2	32.7	0.0	0.3	0.9	1.4	10.4	SICL
T06P05	C'seg	126	12.9	40.5	46.5	0.1	2.0	5.2	3.8	1.9	SIC
T06P05	Cg	169	18.8	61.2	20.0	0.0	1.3	5.6	7.4	4.5	SIL

Appendix C. Moist Aerobic Incubation Data

			pH																						
Pedon	Horizon	Bottom Depth (cm)	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
SP01	Ase1	20	3.4	3.27	3.34		2.69				3.04				3.03	2.99		2.9		2.78			2.67		
SP01	Ase2	48	4.89	3.99	3.85		2.76				2.95				2.98	2.93		2.9		2.67			2.64		
SP01	Cseg1	74	6.27	6.4	5.94		5.22				3.73				3.45	3.4		3.33		3.17			3.01		
SP01	Cseg2	107	6.13	6.12	5.58		3.61				3.6				3.45	3.37		3.33		3.24			3.2		
SP01	Cseg3	145	6.49	6.27	6.51		5.46				4.76				3.84	3.82		3.78		3.65			3.35		
SP01	Cseg4	168	5.49	4.91	4.35		3.27				3.34				3.22	3.14		3.12		3.02			2.8		
SP03	Oe	27	7.37	7.36		6.75		6.49			6.21	6.09		5.67		5.49									
SP03	2Btseg2	86	7.91	8.2		7.32		7.24			6.85	6.72		6.05		5.46									
SP04	ABseg1	21	7.76	7.26		6.23		5.38			4.74	4.37		4		3.62									
SP04	ABseg2	31	8.03	7.49		5.77		4.18			3.41	3.46		2.96		2.84									
SP04	BCtg	116	7.01	7.27		6.92		7.1			6.91	6.91		6.96		6.68									
SP06	Oase1	15	6.65	5.38			4.04			3.9			3.7		3.95	3.99	3.98		3.57				3.85		
SP06	Oase2	28	6.93	6.01			5.17			4.88			4.9		4.9	4.94	4.95		4.07				4.58		
SP06	Ase	38	7.23	6.33			5.36			4.75			4.7		4.04	4.16	4.02		3.37				3.4		
SP06	ABse	48	7.53	6.61			5.07			4.33			3.9		3.64	3.69	3.76		2.92				2.94		
SP06	Bse	56	7.29				6.5			6.39			6.09		6.03	6.04	6.08		5.45				5.2		
T01P04	Ase	10	6.01	6.42			6.21			5.95			5.68		5.28	5.32	5.11		4.68				4.66		
T01P04	Cseg1	39	7.25	7.31			6.96			6.85			6.69		6.48	6.42	6.47		6.15				6.02		
T01P04	Cseg2	66	8.3	8.43			7.69			7.43			7.41		7.39	7.26	7.49		7.26				7.31		
T01P04	Cseg3	112	8.35	8.42			7.64			7.52			7.64		7.54	7.37	7.59		7.46				7.43		
T01P04	Cseg4	142	8.15	8.39			7.59			7.38			7.47		7.39	7.16	7.31		7.12				6.94		
T01P06	Aseg	19	8.27	8.34		8.05		8.2			8.17	8.17		8.11		8.04									
T01P06	2Cseb	71	4.92	4.82		4.6		4.61			4.73	4.69		4.49		4.56									

T01P06	2Csegb	83	4.58	4.23		4.15		4.08			4.19	4.09		3.98		4.05									
T01P08	Aseg	9	6.41	6.05			5.67			5.48			5.39		5.41	5.27	5.28		4.95				5.11		
T01P08	Cseg1	59	7.99	7.49			7.09			6.8			6.46		6.7	6.64	6.76		6.29				6.43		
T01P08	Cseg2	105	8.33	7.97			7.46			7.15			6.96		7.25	7.18	7.33		6.98				7.18		
T01P08	Cseg3	155	8.49	8.19			7.41			7.38			7.33		7.56	7.41	7.5		7.26				7.32		
T01P08	Cseg4	200	7.78	7.51			7.16			7.02			7.13		7.35	7.26	7.29		7.13				7.26		
T01P10	Ase	32	8.78	8.37		7.51		6.5			6.18	5.52		5		4.54									
T01P10	2Btseb	45	7.35	7.43		7.49		7.26			7.16	7.32		7.18		7.02									
T01P10	2Btsegb	83	6.47	6.78		6.67		6.57			6.61	6.7		6.6		6.56									
T01P11	Ase2	22	7.59	7.89		7.37		6.79			6.14	6		5.55		5.09									
T01P11	Cseg	56	7.51	7.75		6.59		5.87			4.9	4.19		3.7		3.41									
T01P11	2Btsegb	106	6.52	7.15		6.21		5.73			5.33	5.04		4.26		4.11									
T01P12	A	21	4.44			2.91		2.91	2.94	2.74		2.13				2.36				2.4	2.42		2.27		
T01P12	2Btsegb1	41	5.4			4.03		4.13	4.07	4.07		3.18				2.94				2.98	2.96		2.9		
T01P12	2Btsegb2	55	5.93			5.56		5.3	5.06	4.97		4.32				4.3				4.12	4.01		3.96		
T01P12	2Btsegb3	91	6.78			6.51		6.55	6.53	6.55		6.41								6.75	6.84		6.64		
T01P12	2CBsegb1	114	7.24			6.95		7.05	6.95	7.06		6.83				7.33				7.47	7.47		7.45		
T01P12	2CBsegb2	135	7.27			7.07		7.16	7.1	7.17		6.9				7.39				7.6	7.63		7.22		
T02P02	Ag	8	8.41	8.35		8.33		8.16			8.16	8.07		7.89		8.01									
T02P02	Cg1	54	8.69	8.05		5.09		3.9			3.64	3.47		3.14		2.68									
T02P02	Cg3	95	8.44	8.37		7.96		7.52			7.07	6.57		5.9		5.41									
T02P04	Ase1	11	5.99	6.25			5.75			5.04			4.89		4.93	4.84	4.52		3.88				4.22		
T02P04	Ase2	38	6.83	6.85			6.43			6.19			5.83		5.59	5.55	5.3		4.41				4.33		
T02P04	Cseg1	88	8.2	8.37			7.68			7.3			7.23		7.19	7.22	7.26		7.09				6.87		
T02P04	Cseg2	113	8.16	8.02			7.44			7.27			7.21		7.12	7.1	7.15		6.97				6.85		
T02P04	Cseg3	163	8.04	7.82			7.16			7.11			7.04		6.85	6.92	6.93		6.54				6.44		
T02P04	Cseg4	200	8.17	7.73			6.6			5.99			5.67		5.22	4.93	4.76		4.19				4.12		
T02P08	Ase	16	6.8			6.68		6.73	6.65	6.76		6.64				6.93				6.83	7.11		6.91		

T02P08	2BC1	32	6.74			6.44		6.54	6.49	6.65		6.35				6.65				6.76	6.75		6.69		
T02P08	2BC2	55	6.71			6.83		6.91	6.9	6.89		6.46				6.83				7.35	7.53		7.34		
T02P08	2CBg	82	6.58			6.4		6.57	6.55	6.55		6.15				6.61				7.06	7.19		7.11		
T03P05	Ase1	14	3.05	3.07	3.15		2.75				3.23				3.34	3.29		3.23		3.15			2.97		
T03P05	Ase2	45	4.36	3.77	3.68		2.53				2.77				2.94	2.89		2.77		2.56			2.53		
T03P05	Cseg1	90	6.38	6.1	5.26		4.58				4.22				3.71	3.69		3.67		3.22			3.14		
T03P05	Cseg2	151	7.06	6.5	6.5		5.82				4.34				3.85	3.81		3.75		3.36			3.21		
T03P05	Cseg3	200	7.26	6.77	6.72		5.21				4.04				3.57	3.54		3.5		3.2			3.02		
T03P07	Ase1	22	8.5	8.37		7.48		6.83			6.3	6.03		5.68		5.4									
T03P07	Ase2	43	8.71	8.56		7.12		6.12			5.11	4.67		4.02		3.65									
T03P07	2BAb	78	7.88	6.76		4.08		3.15			2.67	2.71		2.38		2.29									
T04P01	Ase	24	8.33	8		6.5		5.57			4.51	4.44		3.8		3.59									
T04P01	Cseg1	48	8.72	7.26		4.43		3.91			3.62	3.47		3.19		2.75									
T04P01	Cseg2	68	8.63	8.67		8.08		7.69			7.37	7.39		7.33		7.2									
T05P01	Ase1	15	4.33	3.69	3.44		2.84				3.03				3.04	3.04		2.98		2.82			2.7		
T05P01	Ase2	41	5.79	4.63	4.44		3.16				3.38				3.33	3.28		3.21		3.01			2.94		
T05P01	Cseg1	88	6.46	6.47	5.9		5.07				4.11				3.96	3.96		3.94		3.84			3.51		
T05P01	Cseg2	138	5.97	5.59	5.03		3.91								3.59	3.57		3.55		3.38			3.28		
T05P01	Cseg3	181	5.68	5.14	4.75		3.81				3.84				3.66	3.62		3.63		3.5			3.43		
T05P01	Cseg4	200	5.24	4.91	4.42		3.65				3.94				3.72	3.7		3.72		3.57			3.48		
T05P02	Ase1	17	6.1	5.81			4.26			4.12			3.83		3.89	3.88	3.86		3.29				3.54		
T05P02	Ase2	42	7.26	7.01			6			5.4			4.76		4.35	4.33	4.25		3.55				3.83		
T05P02	Cseg1	85	7.17	7.29			6.47			5.98			5.78		5.06	5.09	4.72		4.07				3.96		
T05P02	Cseg2	114	6.7	6.93			6.22			5.89			5.48		4.66	4.64	4.51		3.56				3.68		
T05P02	Cseg3	162	6.53	6.71			5.95			5.65			4.64		4.33	4.29	4.29		3.64				3.9		
T05P02	Cseg4	200	6.76	6.76			6			6.19			5.47		4.87	4.85	4.61		4.03				3.82		
T05P03	Ase1	10	8.08	6.51	5.31	4.26			2.69			2.7			2.55		3	2.99	3.06		2.62				3.08
T05P03	Ase2	37	8.36	7.52	7.06	6.8			6.26			6.01			5.54		5.45	5.21	4.89		3.99				3.57

T05P03	Cseg1	90	7.77	7.34	6.66	6.41			5.93			5.29			5.1		4.57	4.48	4.31		3.32				3.35
T05P03	Cseg2	128	8.14	7.55	6.54	6.6			6.11			5.65			5.39		4.11	4.26	3.9		3.35				3.4
T05P03	Cseg3	178	7.64	7.52	6.76	6.26			5.24			4.96			5.1		4.79	4.92	4.67		4.17				3.91
T05P03	Cseg4	200	7.77	7.14	6.51	5.96			5.45			5.43			4.95		4.76	4.76	4.82		4.32				4.12
T05P04	Ase1	16	6.95	6.25			4.98			4.61			3.44		3.61	3.54	3.47		2.98				3.35		
T05P04	Ase2	36	7.59	6.85			5.32			5.09			4.36		4.38	4.21	4.18		3.41				3.51		
T05P04	Cseg1	80	7.9	7.3			5.97			5.91			5.36		4.71	4.74	4.58		3.41				3.36		
T05P04	Cseg2	113	8.33	7.74			6.22			5.95			5.25		4.88	4.74	4.6		3.8				3.58		
T05P05	Ase	19	3.75	3.35	3.38		2.53				2.91				2.92	2.82		2.73		2.63			2.42		
T05P05	Aseg	48	5.11	4.75	4.43		2.93				2.98				3.13	3.06		2.95		2.74			2.73		
T05P05	Cseg	71	5.39	5.38	4.95		3.81				3.42				3.44	3.33		3.3		3.3			2.97		
T05P05	Asegb	98	5.92	6.2	5.56		4.8				3.62				3.66	3.59		3.47		3.3			3.17		
T05P05	C'seg1	143	6.66	6.2	6.38		5.76				5.72				4.4	4.46		4.45		4.16			3.97		
T05P05	C'seg2	188	7.11	6.73	6.53		4.31				3.21				2.92	2.98		3.01		2.78			2.63		
T05P05	C'seg3	200	5.39	4.2	4.51		2.54				2.6				2.66	2.65		2.44		2.34			2.15		
T05P07	Ase (0-10 cm)	10	4.64	4.8	4.45		4.04				4.07				3.95	3.82		3.64		3.47			3.3		
T05P07	Ase (10-32 cm)	32	6.77	6.93	6.71		6.03				5.7				5.52	5.35		5.03		4.74			4.38		
T05P08	Cseg1	26	8.06	7.88		7.02		6.51			6.09	5.92		5.35		5.1									
T05P08	C'seg1	37	8.24	7.22		3.9		3.19			2.82	2.81		2.1		2.03									
T05P08	ACg	61	8.21	7.82		7.36		7.68			7.44	7.42		7.49		7.08									
T05P09	Ase	21	5.07	4.44	4.16		3.07				3.19				3.32	3.22		2.99		2.99			2.99		
T05P09	Cseg1	54	6.67	6.21	5.88		4.03				3.77				3.68	3.62		3.43		3.28			3.13		
T05P09	Cseg2	94	6.51	6.6	5.66		4.84				4.16				3.91	3.81		3.67		3.57			3.36		
T05P09	Cseg3	145	6.54	6.77	6.44		6				5.73				5.51	5.39		5.01		4.93			4.5		
T05P09	Cseg4	176	7.31	7.36	7.09		5.87				5.84				4.8	4.74		4.36		4.13			3.73		
T05P09	Cseg5	200	6.87	6.76	6.77		6.26				5.97				5.85	5.79		5.36		4.82			4.02		
T05P10	Aseg	32	6.58	6.12		5.03		4.18			3.81	3.68		3.32		2.87									
T05P10	Cseg1	59	5.16	4.15		3.7		3.22			3.05	2.95		2.68		2.49									

T05P10	Cseg2	122	5.52	4.08		3.39		2.98			2.79	2.73		2.55		2.53									
T05P11	Ase	12	6.56	5.06		4.87		4.78			4.5	3.97		3.57		3.34									
T05P11	Cseg2	22	6.05	5.45		4.09		3.59			3.22	3.09		2.39		2.15									
T05P11	2BCb	86	4.69	4.44		4.43		4.3			4.32	4.25		4.31		4.1									
T06P01	Ase1	9	3.87	3.78	3.69		3.3				3.63				3.51	3.52		3.36		3.34			3.18		
T06P01	Ase2	38	5.96	5.66	5.07		4.72				4.45				4.17	4.18		3.96		3.89			3.74		
T06P01	Ase3	90	6.62	6.39	5.69		4.8				4.46				4.12	4.1		3.88		3.87			3.69		
T06P01	Cseg1	115	5.74	6.27	5.36		4.57				4.38				3.9	3.85		3.75		3.78			3.72		
T06P01	Cseg2	152	5.41	5.21	5.31		3.94				3.61				3.62	3.55		3.43		3.33			3.28		
T06P01	Cseg3	200	6.22	5.94	5.24		4.7				4.41				4.11	4.11		3.86		3.74			3.5		
T06P03	Ase1	14	3.39	3.41	3.45		2.98				3.28				3.34	3.3		3.29		3.28			3.09		
T06P03	Ase2	52	3.84	3.8	3.78		2.97				3.23				3.27	3.18		3.01		2.94			2.92		
T06P03	Cseg1	83	5.9	5.93	4.96		3.95				3.7				3.56	3.54		3.45		3.45			3.16		
T06P03	Cseg2	135	5.68	5.8	5.28		3.83				3.65				3.45	3.41		3.34		3.26			3.2		
T06P03	Cseg3	166	5.53	5.39	4.88		4.07				4.13				3.89	3.87		3.81		3.73			3.53		
T06P03	Cseg4	200	3.39	3.27	3.25		2.27				2.67				2.63	2.68		2.5		2.3			2.15		
T06P05	Ase1	6	3.31	3.28	3.22		2.65				3.08				3.13	3.07		3.06		2.97			2.88		
T06P05	Ase2	25	4.7	4.7	4.31		3.42				3.51				3.46	3.46		3.34		3.13			3.09		
T06P05	Cseg	68	5.47	4.96	4.31		3.4				3.56				3.58	3.54		3.39		3.44			3.23		

Appendix D. Carbon Data

Carbon and nitrogen content of selected samples was determined using a LECO CN628 Carbon/Nitrogen Determinator (LECO Corporation, St. Joseph, MI). Prior to analysis, samples were treated with 10% hydrochloric acid to assess presence of calcium carbonate. Samples that exhibited effervescence were treated with sulfurous acid to remove the calcium carbonate following the method of Balduff (2007).

Pedon	Horizon	Bottom depth (cm)	Material Type	Total N (%)	Total C (%)	C after sulfurous acid treatment (%)	C after sulfurous acid treatment (adjusted 7%)	%OC	%CO3-C	%CaCO3
T06P04	Aseb	86	Buried A	0.06	0.80			0.80	0.00	0.00
T01P04	Ase	10	HFF	0.26	2.34			2.34	0.00	0.00
T01P04	Cseg1	39	HFF	0.20	2.03	1.89	2.02	2.02	0.01	0.10
T01P04	Cseg2	66	HFF	0.21	1.71	1.57	1.68	1.68	0.03	0.29
T01P04	Cseg2	112	HFF	0.26	2.06	1.89	2.03	2.03	0.03	0.28
T01P04	Cseg4	142	HFF	0.25	2.04			2.04	0.00	0.00
T01P11	Ase1	4	HFF	0.28	2.84			2.84	0.00	0.00
T01P11	Ase2	22	HFF	0.25	2.56			2.56	0.00	0.00
T01P11	Cseg	56	HFF	0.12	1.36			1.36	0.00	0.00
T02P04	Ase1	11	HFF	0.33	2.96			2.96	0.00	0.00
T02P04	Ase2	38	HFF	0.26	2.81			2.81	0.00	0.00
T02P04	Cseg1	88	HFF	0.23	1.81			1.81	0.00	0.00
T02P04	Cseg2	113	HFF	0.27	2.23	2.07	2.21	2.21	0.02	0.16
T02P04	Cseg3	163	HFF	0.26	2.18	2.03	2.17	2.17	0.01	0.11
T02P04	Cseg4	200	HFF	0.23	2.04	1.87	2.00	2.00	0.04	0.33
T03P05	Ase1	14	HFF	0.47	4.13			4.13	0.00	0.00
T03P05	Ase2	45	HFF	0.36	3.55			3.55	0.00	0.00
T03P05	Cseg1	90	HFF	0.25	2.34			2.34	0.00	0.00
T03P05	Cseg2	151	HFF	0.23	1.85	1.74	1.86	1.85	0.00	0.00
T03P05	Cseg3	200	HFF	0.34	3.07			3.07	0.00	0.00
T05P03	Ase1	10	HFF	0.36	3.45			3.45	0.00	0.00
T05P03	Ase2	37	HFF	0.26	2.71			2.71	0.00	0.00
T05P03	Cseg1	90	HFF	0.20	2.03			2.03	0.00	0.00
T05P03	Cseg2	128	HFF	0.19	1.54	1.35	1.45	1.45	0.09	0.79
T05P03	Cseg3	178	HFF	0.19	1.69	1.63	1.75	1.69	0.00	0.00
T05P09	Ase	21	HFF	0.41	3.94			3.94	0.00	0.00
T05P09	Cseg1	54	HFF	0.27	2.98	2.76	2.95	2.95	0.03	0.26
T05P09	Cseg2	94	HFF	0.20	1.94			1.94	0.00	0.00
T05P09	Cseg3	145	HFF	0.22	2.21			2.21	0.00	0.00
T05P09	Cseg4	176	HFF	0.28	3.04	2.83	3.03	3.03	0.01	0.08
T05P09	Cseg5	200	HFF	0.31	3.22	3.22	3.44	3.22	0.00	0.00

T06P04	Ase	22	HFF	0.26	2.66			2.66	0.00	0.00
T06P04	Aseg	46	HFF	0.15	1.59	1.65	1.77	1.59	0.00	0.00
T06P04	Cseg	122	HFF	0.09	1.34	1.29	1.38	1.34	0.00	0.00
T06P05	Ase1	6	HFF	0.46	4.37	4.35	4.65	4.37	0.00	0.00
T06P05	Ase2	25	HFF	0.40	3.91			3.91	0.00	0.00
T06P05	Ase3	42	HFF	0.27	2.82	2.84	3.04	2.82	0.00	0.00
T06P05	Cseg	68	HFF	0.21	1.96	1.82	1.94	1.94	0.01	0.10
T06P05	Aseb	96	HFF	0.21	1.81	1.71	1.83	1.81	0.00	0.00
T06P05	C'seg	126	HFF	0.18	1.82			1.82	0.00	0.00
T06P05	Cg	169	HFF	0.46	4.80			4.80	0.00	0.00
SP03	Ase	7	HS	0.19	3.53	4.22	4.51	3.53	0.00	0.00
T01P06	Aseg	19	HS	0.01	0.09			0.09	0.00	0.00
T01P06	Cseg1	32	HS	0.01	0.07			0.07	0.00	0.00
T01P06	Cseg2	46	HS	0.01	0.06			0.06	0.00	0.00
T01P06	Cseg3	62	HS	0.00	0.08			0.08	0.00	0.00
T01P10	Ase	32	HS	0.02	0.19			0.19	0.00	0.00
T01P12	A	21	HS	0.05	1.14	0.94	1.01	1.01	0.13	1.06
T02P02	Ag	8	HS	0.00	0.09	0.08	0.09	0.09	0.00	0.04
T02P02	Cg1	54	HS	0.00	0.11			0.11	0.00	0.00
T02P02	Cg2	69	HS	0.01	0.24			0.24	0.00	0.00
T02P02	Cg3	95	HS	0.00	0.10			0.10	0.00	0.00
T02P02	Cg4	138	HS	0.15	1.45			1.45	0.00	0.00
T02P02	Cg5	158	HS	0.02	0.30			0.30	0.00	0.00
T02P07	Ase	18	HS	0.02	0.11			0.11	0.00	0.00
T02P07	AC	37	HS	0.01	0.12			0.12	0.00	0.00
T02P07	Cg1	71	HS	0.01	0.13			0.13	0.00	0.00
T02P07	Cg2	113	HS	0.00	0.16			0.16	0.00	0.00
T02P07	AC'b	147	HS	0.03	1.02	0.81	0.87	0.87	0.15	1.22
T02P08	Ase	16	HS	0.01	0.09	0.09	0.09	0.09	0.00	0.00
T03P07	Ase1	22	HS	0.01	0.11	0.07	0.08	0.08	0.03	0.27
T03P07	Ase2	43	HS	0.01	0.13			0.13	0.00	0.00
T03P07	Ase3	57	HS	0.03	0.40	0.25	0.27	0.27	0.14	1.14
T04P01	Ase	24	HS	0.00	0.10	0.07	0.07	0.07	0.03	0.23
T04P01	Cseg1	48	HS	-0.01	0.09			0.09	0.00	0.00
T04P01	Cseg2	68	HS	0.00	0.16			0.16	0.00	0.00
T04P01	Cseg3	82	HS	0.00	0.19			0.19	0.00	0.00
T04P01	Cseg4	128	HS	0.01	0.25			0.25	0.00	0.00
T04P01	Cseg5	164	HS	0.05	0.52			0.52	0.00	0.00
T04P01	Cseg6	176	HS	0.07	0.82			0.82	0.00	0.00
T04P01	Cseg7	253	HS	0.07	0.89			0.89	0.00	0.00

T04P01	Cseg8	282	HS	0.03	0.51	0.45	0.48	0.48	0.02	0.19
T04P01	Cseg9	300	HS	0.00	0.22			0.22	0.00	0.00
T05P03	Cseg4	200	HS	0.35	3.90	3.85	4.12	3.90	0.00	0.00
T05P08	Ase	3	HS	0.07	0.87	0.83	0.89	0.87	0.00	0.00
T05P08	Cseg1	26	HS	0.06	0.80	1.02	1.09	0.80	0.00	0.00
T05P08	Cseg2	37	HS	0.04	0.48			0.48	0.00	0.00
T05P08	ACg	61	HS	0.01	0.26	0.25	0.27	0.26	0.00	0.00
T05P08	C'seg1	83	HS	-0.22	0.23	0.17	0.18	0.18	0.05	0.45
T05P08	C'seg2	135	HS	0.00	0.31	0.33	0.35	0.31	0.00	0.00
T05P10	Ase	13	HS	0.05	0.68	0.58	0.62	0.62	0.05	0.44
T05P10	Aseg	32	HS	0.02	0.44	0.39	0.41	0.41	0.02	0.21
T05P10	Cseg1	59	HS	-0.01	0.10			0.10	0.00	0.00
T05P10	Cseg2	122	HS	0.01	0.18			0.18	0.00	0.00
T05P10	Cseg3	165	HS	0.00	0.09			0.09	0.00	0.00
T05P11	Ase	12	HS	0.00	0.20			0.20	0.00	0.00
T05P11	Cseg1	22	HS	0.02	0.50			0.50	0.00	0.00
T05P11	Cseg2	40	HS	0.03	0.72			0.72	0.00	0.00
SP03	Oe	27	Organic	1.37	27.80			27.80	0.00	0.00
SP03	2A'se	46	T	0.13	3.67			3.67	0.00	0.00
SP03	2Eseg	55	T	-0.01	0.53			0.53	0.00	0.00
SP03	2Btseg1	69	T	0.00	0.48			0.48	0.00	0.00
SP03	2Btseg2	86	T	0.00	0.58			0.58	0.00	0.00
SP03	2Btseg3	117	T	-0.01	0.18			0.18	0.00	0.00
SP04	Ase	11	T	0.21	4.48	4.98	5.33	4.48	0.00	0.00
SP04	ABseg1	21	T	0.01	1.30			1.30	0.00	0.00
SP04	ABseg2	31	T	-0.01	0.78			0.78	0.00	0.00
SP04	Btg1	50	T	-0.02	0.41			0.41	0.00	0.00
SP04	Btg2	66	T	0.01	0.72			0.72	0.00	0.00
SP04	BCt	78	T	-0.03	0.25			0.25	0.00	0.00
SP04	BCtg	116	T	-0.03	0.14			0.14	0.00	0.00
T01P06	2Cseb	71	T	0.02	0.18			0.18	0.00	0.00
T01P06	2Csegb	83	T	0.01	0.07			0.07	0.00	0.00
T01P06	2C'seb	97	T	0.03	0.22			0.22	0.00	0.00
T01P10	2Btseb	45	T	0.01	0.08			0.08	0.00	0.00
T01P10	2Btsegb	83	T	0.01	0.12			0.12	0.00	0.00
T01P11	2Btsegb	106	T	0.05	0.47			0.47	0.00	0.00
T01P11	2BCsegb	165	T	0.02	0.17	0.17	0.18	0.17	0.00	0.00
T01P12	2Btsegb1	41	T	0.03	0.57			0.57	0.00	0.00
T01P12	2Btsegb2	55	T	0.04	0.45			0.45	0.00	0.00
T01P12	2Btsegb3	91	T	0.02	0.18			0.18	0.00	0.00

T01P12	2CBsegb1	114	T	0.01	0.09			0.09	0.00	0.00
T01P12	2CBsegb2	135	T	0.01	0.08			0.08	0.00	0.00
T02P07	2Ab	160	T	0.12	2.68			2.68	0.00	0.00
T02P07	2Egb	168	T	0.02	0.47			0.47	0.00	0.00
T02P07	2CBb1	219	T	0.01	0.13			0.13	0.00	0.00
T02P07	2CBb2	244	T	0.00	0.06			0.06	0.00	0.00
T02P08	2BC1	32	T	-0.01	0.03			0.03	0.00	0.00
T02P08	2BC2	55	T	0.00	0.03			0.03	0.00	0.00
T02P08	2CBg	82	T	0.00	0.02			0.02	0.00	0.00
T03P07	2BAb	78	T	0.05	1.11			1.11	0.00	0.00
T03P07	2Btgb	103	T	0.04	0.95			0.95	0.00	0.00
T03P07	2BCgb1	116	T	0.00	0.06			0.06	0.00	0.00
T03P07	2BCgb2	130	T	0.00	0.10			0.10	0.00	0.00
T03P07	2C	159	T	0.00	0.06			0.06	0.00	0.00
T05P11	2Bwb	50	T	-0.01	0.17			0.17	0.00	0.00
T05P11	2BCb	86	T	0.00	0.04			0.04	0.00	0.00
T06P04	2Cg1	142	T	0.39	4.28	4.57	4.89	4.28	0.00	0.00
T06P04	2Cg2	185	T	0.18	4.01			4.01	0.00	0.00
T06P04	2Cg3	236	T	0.14	3.62			3.62	0.00	0.00

Appendix E. Data Comparison Matrices

These are the comparison matrices generated during the evaluation of the Rhode river soil-landscape relationship model. Each South River pedon was compared to each of the seven soil series proposed in the Rhode River study (Wessel, 2020). The bolded numbers in green cells represent the soil series mapped at the pedon location (based on the Rhode River model).

Comparison Scheme 1 (original Rhode River scheme)	
Class	Criteria
1	Observed soil shares no noteworthy properties with the predicted series and is formed in different parent materials
2	Observed soil is formed in the same parent materials as predicted series (Holocene mineral, Tertiary mineral, organic)
3	Observed soil matches the taxonomic subgroup of the predicted series
4	Observed soil is similar to the predicted series (i.e., shares most interpretive properties)
5	Observed soil matches predicted soil series

	Comparison Scheme 1 (original Rhode River scheme)						
Pedon	Contees Wharf	Dutchman Point	Fox Creek	Muddy Creek	Rhode River	Sand Point	Sellman
SP01	2	**1**	1	1	1	1	2
SP03	1	1	**2**	1	2	2	1
SP04	1	1	**1**	1	1	1	1
SP06	1	1	**2**	1	1	1	1
T01P01	2	1	1	1	1	1	**2**
T01P02	1	2	1	1	**2**	2	1
T01P03	2	**1**	1	1	1	1	2
T01P04	**2**	1	1	1	1	1	3
T01P05	1	**2**	1	1	1	1	3
T01P06	1	2	1	1	**2**	2	1
T01P07	2	**2**	1	1	2	2	1
T01P08	2	1	1	1	1	1	**2**
T01P09	1	**2**	1	1	2	2	1
T01P10	1	**2**	1	1	2	2	1
T01P11	2	1	1	1	**1**	1	1
T01P12	1	2	**1**	1	2	2	1

T02P01	2	2	1	1	**1**	1	1
T02P02	1	2	1	1	**1**	1	1
T02P03	1	**2**	1	1	1	1	1
T02P04	**2**	1	1	1	1	1	2
T02P05	2	1	1	1	1	1	**2**
T02P06	**1**	2	1	1	1	1	1
T02P07	1	**2**	1	1	2	2	1
T02P08	1	2	1	1	**2**	2	1
T03P01	1	2	1	1	**2**	2	1
T03P02	1	2	1	1	2	2	**1**
T03P03	1	2	1	1	2	2	**1**
T03P04	1	2	1	1	**2**	2	1
T03P05	2	1	1	1	1	1	**2**
T03P06	1	**2**	1	1	2	2	1
T03P07	1	2	1	1	**2**	2	1
T04P01	1	2	1	1	**1**	1	1
T04P02	1	**2**	1	1	1	1	1
T04P03	2	1	1	1	1	1	**2**
T04P04	1	**2**	1	1	1	1	1
T04P05	1	2	1	1	**1**	1	1
T05P01	2	1	**1**	1	1	1	2
T05P02	2	1	1	1	1	1	**2**
T05P03	2	1	1	1	1	1	**2**
T05P04	2	**1**	1	1	1	1	1
T05P05	2	1	1	1	1	1	**2**
T05P06	1	**2**	1	1	1	1	1
T05P07	1	2	1	1	**2**	2	1
T05P08	1	**2**	1	1	1	1	1
T05P09	**2**	1	1	1	1	1	2
T05P10	1	**2**	1	1	1	1	1
T05P11	1	2	1	1	**2**	2	1
T06P01	2	1	**1**	1	1	1	2
T06P02	2	1	1	1	**1**	1	1
T06P03	2	1	1	1	1	1	**2**
T06P04	2	**1**	1	1	1	1	1
T06P05	2	1	1	1	1	1	**2**

Comparison Scheme 2 (revised Rhode River scheme)	
Class	Criteria
1	Observed soil possesses none of the diagnostic materials or horizons of the predicted series within 2 m of the soil surface. Unexpected diagnostic horizons or materials are present within 2 m of the soil surface (Cambic Horizon and Ochric Epipedon exempted).
2	One or more predicted diagnostic horizons or materials of the predicted series are absent from within 2 m of the soil surface AND unexpected diagnostic horizons or materials are present within 2 m of the soil surface (Cambic Horizon and Ochric Epipedon exempted).
3	One or more predicted diagnostic horizons or materials of the predicted series are absent from within 2 m of the soil surface OR unexpected diagnostic horizons or materials are present within 2 m of the soil surface (Cambic Horizon and Ochric Epipedon exempted).
4	All diagnostic horizons and/or materials of the predicted series are present within 2 m of the soil surface. No unexpected diagnostic horizons or materials are present within 2 m of the soil surface.
5	Observed soil matches the predicted series.

	Comparison Scheme 2 (revised Rhode River scheme)						
Pedon	Contees Wharf	Dutchman Point	Fox Creek	Muddy Creek	Rhode River	Sand Point	Sellman
SP01	4	**2**	3	3	1	2	3
SP03	2	2	**3**	2	3	2	2
SP04	3	2	**3**	3	2	3	1
SP06	3	2	**3**	4	2	2	1
T01P01	4	1	3	3	1	2	**3**
T01P02	2	3	3	2	**2**	4	1
T01P03	4	**1**	3	3	1	2	2
T01P04	**4**	2	3	3	1	2	2
T01P05	3	**3**	3	2	3	3	2
T01P06	3	4	3	2	**3**	3	2
T01P07	3	**3**	3	2	3	3	2
T01P08	3	2	3	3	1	1	**4**
T01P09	1	**4**	3	2	4	3	2
T01P10	2	**4**	3	2	4	3	2
T01P11	3	2	3	3	**2**	2	2
T01P12	3	4	**3**	2	3	4	1
T02P01	3	2	3	2	**2**	2	2
T02P02	2	3	3	2	**2**	3	1
T02P03	2	**2**	3	2	2	3	1
T02P04	**3**	2	3	3	1	1	4

T02P05	4	1	3	3	1	2	**2**
T02P06	**2**	2	3	2	2	3	1
T02P07	1	**4**	3	2	3	3	2
T02P08	2	3	3	2	**4**	3	2
T03P01	2	3	3	2	**2**	4	1
T03P02	2	3	3	2	2	4	**1**
T03P03	2	3	3	2	2	4	**1**
T03P04	2	3	3	2	**3**	4	1
T03P05	4	2	3	3	1	2	**3**
T03P06	2	**3**	3	2	2	4	1
T03P07	2	4	3	2	**3**	4	1
T04P01	2	3	3	2	**2**	3	1
T04P02	2	**2**	3	2	2	3	1
T04P03	4	1	3	3	1	2	**2**
T04P04	2	**2**	3	2	2	3	1
T04P05	2	2	3	2	**2**	3	1
T05P01	4	1	**3**	3	1	2	2
T05P02	4	1	3	3	1	2	**2**
T05P03	4	2	3	2	2	2	**2**
T05P04	3	**2**	3	2	2	2	2
T05P05	3	1	3	2	1	2	**2**
T05P06	2	**2**	3	2	2	3	1
T05P07	2	2	3	2	**2**	4	1
T05P08	2	**3**	3	2	2	3	1
T05P09	**4**	2	3	3	1	2	3
T05P10	2	**3**	3	2	2	4	1
T05P11	2	4	3	2	**2**	4	1
T06P01	4	1	**3**	3	1	2	2
T06P02	3	1	3	2	**1**	2	2
T06P03	4	1	3	3	1	2	**2**
T06P04	3	**2**	3	3	2	2	2
T06P05	4	1	3	3	1	2	**2**

Comparison Scheme 3 (South River scheme)	
Class	Criteria
1	Observed soil has no meaningful similarities to the expected soil
Material type questions: - Within 100 cm, are there ≥10 cm nonfluid materials? - Within 100 cm, are there ≥10 cm slightly fluid to very fluid materials? - Within 100 cm, is there tertiary material (paleosol)?	
2	Observed soil has one out of three material type questions correct
3	Observed soil has two out of three material type questions correct
4	Observed soil has all three material type questions correct
5	Observed soil is similar to expected soil (i.e., shares most interpretive properties)
6	Observed soil matches the predicted series

	Comparison Scheme 3 (South River scheme)						
Pedon	Contees Wharf	Dutchman Point	Fox Creek	Muddy Creek	Rhode River	Sand Point	Sellman
SP01	5	**2**	3	4	1	1	4
SP03	2	2	**3**	2	4	4	1
SP04	2	2	**3**	2	4	4	1
SP06	2	1	**2**	2	4	3	2
T01P01	4	2	3	4	1	1	**4**
T01P02	1	3	2	1	**4**	4	1
T01P03	4	**2**	3	4	1	1	4
T01P04	**5**	2	3	4	1	1	4
T01P05	2	**2**	3	2	4	4	1
T01P06	1	3	2	1	**4**	4	1
T01P07	2	**2**	3	2	3	3	2
T01P08	5	3	3	4	1	1	**5**
T01P09	1	**3**	2	1	5	4	1
T01P10	1	**3**	2	1	4	4	1
T01P11	3	1	3	3	**3**	3	3
T01P12	2	2	**3**	2	4	4	1
T02P01	3	3	4	3	**2**	2	3
T02P02	2	4	3	2	**3**	3	2
T02P03	2	**4**	3	2	3	3	2
T02P04	**5**	2	3	4	1	1	5
T02P05	4	2	3	4	1	1	**4**
T02P06	**3**	3	4	3	2	2	3
T02P07	2	**4**	3	2	3	3	2
T02P08	1	3	2	1	**5**	4	1

T03P01	1	3	2	1	**4**	4	1
T03P02	1	3	2	1	4	4	**1**
T03P03	1	3	2	1	4	5	**1**
T03P04	1	3	2	1	**4**	5	1
T03P05	5	2	3	4	1	1	**4**
T03P06	2	**3**	3	2	3	3	2
T03P07	1	3	2	1	**4**	4	1
T04P01	2	4	3	2	**3**	3	2
T04P02	2	**4**	3	2	3	3	2
T04P03	4	2	3	4	1	1	**4**
T04P04	2	**4**	3	2	3	3	2
T04P05	2	4	3	2	**3**	3	2
T05P01	4	2	**3**	4	1	1	4
T05P02	4	2	3	4	1	1	**4**
T05P03	5	2	3	4	1	1	**4**
T05P04	4	**3**	4	4	1	2	4
T05P05	4	2	3	4	1	1	**4**
T05P06	2	**4**	3	2	3	3	2
T05P07	2	4	3	2	**3**	3	2
T05P08	2	**4**	3	2	3	3	2
T05P09	**5**	2	3	4	1	1	4
T05P10	2	**5**	3	2	3	3	2
T05P11	1	3	2	1	**3**	3	2
T06P01	4	2	**3**	4	1	1	4
T06P02	4	2	3	4	**1**	1	4
T06P03	4	2	3	4	1	1	**4**
T06P04	4	**2**	3	4	1	1	4
T06P05	4	2	3	4	1	1	**4**

Appendix F. Draft Official Series Descriptions for Proposed Soil Series

LOCATION BROAD CREEK MD

Tentative Series

CEP

01/2021

BROAD CREEK SERIES

Series proposed for the soils found on Tidal Creek Channel landforms in South River. These soils are composed of stratified Holocene fluid fine materials. They differ from the proposed series for DEC/EC/MC soils (which are also composed of Holocene fluid fines) bc they have a buried A horizon. These landforms were mapped as Contees Wharf and Sellman in the draft map, but they differ from those series because of PSFC and hypersulfidic materials.

MLRA(s): 149A

Soil Survey Regional Office (SSRO) Responsible:

Depth Class: Very Deep

Drainage Class: Subaqueous (permanently submersed/continuously inundated)

Saturated Hydraulic Conductivity: Low to Moderately High

Parent Material: fine-loamy, mixed estuarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 57 degrees F (14 degrees C)

Mean Annual Water Temperature: 57 degrees F (14 degrees C)

TAXONOMIC CLASS: fine-loamy, mixed, subactive, nonacid, mesic Fluventic Sulfiwassents

TYPICAL PEDON: Broad Creek silt loam on a permanently submersed tidal creek channel landform with less than 3 percent slope under 3 meters of estuarine water. (Colors are for moist soils unless otherwise noted).

Ase1 – 0 to 6 cm; black (N 2.5/0) loam; massive; very fluid; slight hydrogen sulfide odor; ultra acid (pH 3.31), ultra acid (pH 2.88) after 16 weeks; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary.

Ase2 – 6 to 25 cm; black (N 2.5/0) loam; massive; very fluid; slight hydrogen sulfide odor; very strongly acid (pH 4.7), ultra acid (pH 3.09) after 16 weeks; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary.

Ase3 – 25 to 42 cm; greenish black (10Y 2.5/1) silt loam; massive; very fluid; slight petrochemical odor; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary.

Cseg – 42 to 68 cm; greenish black (5GY 2.5/1) clay loam; massive; very fluid; slight petrochemical odor; strongly acid (pH 5.47), ultra acid (pH 3.23) after 16 weeks; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary.

Aseb – 68 to 96 cm; black (N 2.5/0) silty clay loam; massive; moderately fluid; slight hydrogen sulfide odor; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary.

C'seg – 96 to 126 cm; dark greenish gray (5GY 3/1) silty clay; massive; slightly fluid; slight petrochemical odor; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary.

Cg – 126 to 169 cm; dark greenish gray (10Y 3/1) silt loam; massive; slightly fluid; 3% shell fragments by volume; no color reaction with 3% peroxide, very slightly effervescent with 30% peroxide.

TYPE LOCATION: Anne Arundel County, Maryland; South River, Broad Creek, 580 m north of Porter Point (sampling point T06P05); USGS South River topographic quadrangle; latitude 38.964394 decimal degrees, longitude -76.576697 decimal degrees, UTM Zone 18N WGS 1984; Major Land Resource Area 149A.

RANGE IN CHARACTERISTICS:

Depth to Bedrock: Greater than 200 cm

Depth to Seasonally High Water Table: Permanently Submersed

Depth to Hypersulfidic Materials (incubated pH $\leq$4.0): 0 to 50 cm

Manner of Failure/Fluidity Class: Slightly Fluid to Very Fluid

Shell Fragments: 0 to 5 percent by volume

Soil Reaction: Ultra Acid to Moderately Alkaline; Oxidized Reaction: Ultra Acid

Salinity Range is 3 to 16 (ppt)

Tidal Range is 0 to 2 feet (0 to 0.6 meters)

Water Depth is 0 to 4 feet (0 to 1.5 meters)

Up to 15% glauconite by weight in the fine-earth fraction

RANGE OF INDIVIDUAL HORIZONS:

Ase or Aseg horizon:

Color – hue of N, 10Y, 5GY, or 10GY; value of 2.5 or 3; chroma of 0 or 1

Texture – loam or silt loam

Consistence – very fluid

Cseg or Cg horizon:

Color – hue of N, 10Y, 5GY, or 10GY; value of 2.5 or 3; chroma of 0 or 1

Texture – sandy loam, loam, silt loam, clay loam, silty clay loam, clay

Consistence – slightly fluid to very fluid

Aseb or Asegb horizon:

Color – hue of N; value of 2.5; chroma of 0

Texture – loam or silt loam

Consistence – moderately fluid

C'seg horizon:

Color – hue of 5GY or 10GY; value of 2.5 or 3; chroma of 1

Texture – loam, silty clay loam, or silty clay

Consistence – slightly fluid or moderately fluid

COMPETING SERIES:

Cornballer – mapped on Estuarine Channel and Mainland Cove landforms; does not contain buried A material

GEOGRAPHIC SETTING:

Landscape: Northern Coastal Plain Subestuaries

Landform: Tidal Creek Channel

Parent Material: fine-loamy, mixed estuarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 50 to 59 degrees F (10 to 15 degrees C)

Mean Annual Water Temperature: 52 to 58 degrees F (11 to 14 degrees C)

Bathymetry: 0 to 4 feet (0 to 1.5 meters)

Water Regime: Tidal; 0 to 2 feet (0 to 0.6 meters)

Water Salinity Range: 3 to 16 ppt

GEOGRAPHICALLY ASSOCIATED SOILS:

Cornballer soils – mapped on Estuarine Channel and Mainland Cove landforms; composed of Holocene fluid fine material; contains hypersulfidic materials.

Duvall Creek soils – mapped on Wave-Built Terrace landforms; composed of Holocene sandy material; includes hypersulfidic materials and a buried shell layer.

Glebe Bay soils – mapped on Submerged Shoal/Saddle landforms; composed of Holocene sandy material overlying Tertiary material; contains hypersulfidic materials.

Long Point soils – mapped on Submerged Tidal Marsh landforms; composed of Holocene sandy material and hemic organic material overlying a relatively intact paleosol; contains hypersulfidic materials.

Overboard soils – mapped on Tidal Creek Platform landforms; composed of Holocene fluid fine material overlying Tertiary material; includes hypersulfidic materials and a buried A horizon

South River soils – mapped on Wave-Cut Platform landforms; composed of Holocene sandy material overlying Tertiary material; has glauconitic mineralogy, hypersulfidic materials, and horizons with chroma 3 or more between 15 and 100 cm.

DRAINAGE AND HYDRAULIC CONDUCTIVITY:

Drainage Class: Subaqueous

Saturated Hydraulic Conductivity: Low to Moderately High

Soil Moisture Regime: Peraquic

Soil is permanently submerged with salt or brackish water with a range of 3 to 16 ppt. The presence of hypersulfidic materials within 50 cm of the soil surface puts these soils at risk for potential acid sulfate soil formation if they are dredged and exposed to air.

USE AND VEGETATION:

Major Uses: Most areas of this soil are used for recreational fishing, swimming, and boating. Commercial uses include shell fishing and aquaculture (The upper part of South River (starting at Glebe Bay) is an oyster sanctuary).

Dominant Vegetation: Benthic fauna such as clams, blue crabs, and oysters are associated with this soil. Eelgrass (*Zostera marina*), sea lettuce (*Ulva sp.*), and horned pondweed (*Zannichellia palustris*) may occur on these soils.

DISTRIBUTION AND EXTENT: Northern Atlantic Coastal Plain subestuaries of the western portion of Chesapeake Bay (Maryland). MLRA 149A. This series is of small extent.

SOIL SURVEY REGIONAL OFFICE (SSRO) RESPONSIBLE:

SERIES ESTABLISHED: Anne Arundel County, Maryland, 2021.

REMARKS: This subaqueous soil series is named for Broad Creek, a feature of South River. Areas of Broad Creek soils were formerly included with water.

Diagnostic horizons and other diagnostic soil characteristics recognized in this pedon are:

Ochric epipedon – the zone from 0 to 42 cm (Ase horizons)

Peraquic feature – the zone from 0 to 169 cm is permanently saturated

Hypersulfidic materials – the zone from 0 to 169 cm

Buried A horizon – the zone from 68 to 96 cm is organic enriched and black; indicates a former soil surface

This series contains up to 15% glauconite (clay-sized) in the fine-earth fraction.

LOCATION CORNBALLER MD

Tentative Series

CEP

01/2021

CORNBALLER SERIES

Series proposed for the Holocene fluid fine soils found in South River on Deep Estuarine Channel, Estuarine Channel, and Mainland Cove landforms. These landforms were mapped as Contees Wharf or Sellman, but our observations revealed that the soils were hypersulfidic, meaning the mapped series was not a good match.

MLRA(s): 149A

Soil Survey Regional Office (SSRO) Responsible:

Depth Class: Deep

Drainage Class: Subaqueous (permanently submersed/continuously inundated)

Saturated Hydraulic Conductivity: Moderately Low to High

Parent Material: fine-loamy, mixed estuarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 57 degrees F (14 degrees C)

Mean Annual Water Temperature: 57 degrees F (14 degrees C)

TAXONOMIC CLASS: fine-loamy, mixed, subactive, nonacid, mesic Fluventic Sulfiwassents

TYPICAL PEDON: Cornballer silt loam on a permanently submersed, southeast flowing estuarine channel with 1 percent slope under 4.5 meters of estuarine water in South River. (Colors are for moist soils unless otherwise noted).

Ase – 0 to 10 cm; greenish black (10GY 2.5/1) silty clay loam; massive; moderately fluid; slight petrochemical odor; neutral (pH 6.65), extremely acid (pH 3.57) after 16 weeks; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary.

Cseg1 – 10 to 39 cm; very dark greenish gray (10Y 3/1) loam; massive; moderately fluid; 1 percent shell fragments by volume; slight petrochemical odor; neutral (pH 6.93), extremely acid (pH 4.07) after 16 weeks; color reaction with 3% peroxide, strongly effervescent with 30% peroxide; clear boundary.

Cseg2 – 39 to 66 cm; very dark greenish gray (5GY 3/1) loam; massive; moderately fluid; slight petrochemical odor; neutral (7.23 pH), ultra acid (pH 3.37) after 16 weeks; color reaction with 3% peroxide, strongly effervescent with 30% peroxide; clear boundary.

Cseg3 – 66 to 112 cm; very dark greenish gray (10GY 3/1) loam; massive; moderately fluid; 1 percent shell fragments by volume; slight petrochemical odor; slightly alkaline (pH 7.53), ultra acid (pH 2.92) after 16 weeks; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; gradual boundary.

Cseg4 – 112 to 142 cm; very dark greenish gray (5GY 3/1) loam; massive; slightly fluid; 1 percent shell fragments by volume; slight petrochemical odor; neutral (pH 7.29), strongly acid (pH 5.2) after 16 weeks; color reaction with 3% peroxide, slightly effervescent with 30% peroxide.

TYPE LOCATION: Anne Arundel County, Maryland; South River, 900 meters south of Hill Point and 950 meters east of Long Point (sampling point T01P04); USGS South River topographic quadrangle; latitude 38.916252 decimal degrees, longitude -76.496852 decimal degrees, UTM Zone 18N WGS 1984; Major Land Resource Area 149A.

RANGE IN CHARACTERISTICS:

Depth to Bedrock: Greater than 200 cm

Depth to Seasonally High Water Table: Permanently Submersed

Depth to Hypersulfidic Materials (incubated pH $\leq$4.0): 0 to 50 cm

Manner of Failure/Fluidity Class: Slightly Fluid to Moderately Fluid throughout

Shell Fragments: 0 to 1 percent by volume throughout

Soil Reaction: Neutral to Slightly Alkaline; Oxidized Reaction: Ultra Acid to Strongly Acid

Salinity Range is 3 to 16 (ppt)

Tidal Range is 0 to 2 feet (0 to 0.6 meters)

Water Depth is 4.5 meters

Up to 15% glauconite by weight in the fine-earth fraction

RANGE OF INDIVIDUAL HORIZONS:

Ase horizon:

Color – hue N, 10Y, 5GY, or 10GY; value 2.5; chroma 0 or 1

Texture – sandy loam, loam, silt loam, or silty clay loam

Consistence – moderately fluid to very fluid

Cseg or Cg horizon:

Color – hue 10Y, 5GY, or 10GY; value 2.5, 3, or 4; chroma 1

Texture – sand, loamy sand, sandy loam, loam, sandy clay loam, or clay loam

Consistence – nonfluid to very fluid

COMPETING SERIES:

Figgs soils – mapped on lagoon bottom landforms in the saline waters of coastal bays (MLRA 153D); contain a lithological discontinuity

GEOGRAPHIC SETTING:

Landscape: Northern Coastal Plain Subestuaries

Landform: Estuarine Channel, Mainland Cove

Parent Material: fine-loamy, mixed estuarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 50 to 59 degrees F (10 to 15 degrees C)

Mean Annual Water Temperature: 52 to 58 degrees F (11 to 14 degrees C)

Bathymetry: 0 to 31 feet (0 to 9 meters)

Water Regime: Tidal; 0 to 2 feet (0 to 0.6 meters)

Water Salinity Range: 3 to 16 ppt

GEOGRAPHICALLY ASSOCIATED SOILS:

Broad Creek soils – mapped on Tidal Creek Channel landforms; composed of Holocene fluid fine material; includes hypersulfidic materials and a buried A horizon.

Duvall Creek soils – mapped on Wave-Built Terrace landforms; composed of Holocene sandy material; includes hypersulfidic materials and a buried shell layer.

Glebe Bay soils – mapped on Submerged Shoal/Saddle landforms; composed of Holocene sandy material overlying Tertiary material; contains hypersulfidic materials.

Long Point soils – mapped on Submerged Tidal Marsh landforms; composed of Holocene sandy material and hemic organic material overlying a relatively intact paleosol; contains hypersulfidic materials.

Overboard soils – mapped on Tidal Creek Platform landforms; composed of Holocene fluid fine material overlying Tertiary material; includes hypersulfidic materials and a buried A horizon

South River soils – mapped on Wave-Cut Platform landforms; composed of Holocene sandy material overlying Tertiary material; has glauconitic mineralogy, hypersulfidic materials, and horizons with chroma 3 or more between 15 and 100 cm.

DRAINAGE AND HYDRAULIC CONDUCTIVITY:

Drainage Class: Subaqueous

Saturated Hydraulic Conductivity: Moderately Low to High

Soil Moisture Regime: Peraquic

Soil is permanently submerged with salt or brackish water with a range of 3 to 16 ppt. The presence of hypersulfidic materials within 50 cm of the soil surface puts these soils at risk for potential acid sulfate soil formation if they are dredged and exposed to air.

USE AND VEGETATION:

Major Uses: Most areas of this soil are used for recreational fishing, swimming, and boating. Commercial uses include shell fishing and aquaculture (The upper part of South

River (starting at Glebe Bay) is an oyster sanctuary).

Dominant Vegetation: Benthic fauna such as clams, blue crabs, and oysters are associated with this soil. Eelgrass (*Zostera marina*), sea lettuce (*Ulva sp.*), and horned pondweed (*Zannichellia palustris*) may occur on these soils.

DISTRIBUTION AND EXTENT: Northern Atlantic Coastal Plain subestuaries of the western portion of Chesapeake Bay (Maryland). MLRA 149A. This series is of small extent.

SOIL SURVEY REGIONAL OFFICE (SSRO) RESPONSIBLE:

SERIES ESTABLISHED: Anne Arundel County, Maryland, 2021.

REMARKS: This subaqueous soil series is named for the research vessel used in the study of South River subaqueous soils. It was lovingly nicknamed the Cornballer as an homage to the TV show Arrested Development. The boat, being entirely metal, was scalding, much like George Bluth's ill-fated appliance. Ron Howard, please don't sue us.

Areas of Cornballer soils were formerly included with water.

Diagnostic horizons and other diagnostic soil characteristics recognized in this pedon are:

Ochric epipedon – the zone from 0 to 10 cm (Ase horizon)

Peraquic feature – the zone from 0 to 142 cm is permanently saturated

Hypersulfidic materials – the zone from 0 to 112 cm

This soil contains up to 15% glauconite (clay-sized) in the fine-earth fraction.

LOCATION DUVALL CREEK MD

Tentative Series

CEP

01/2021

DUVALL CREEK SERIES

Series proposed for the soils found on Wave-Built Terrace landforms in South River, Md. These soils were composed of stratified deposits of Holocene sands; they were classified as Sulfic Psammowassents because of their texture and presence of hypersulfidic materials. This proposed series differs from the Dutchman Point series (which captures the sandy, Holocene-aged soils on Wave-Built Terrace landforms in Rhode River) because it contains hypersulfidic materials, a buried shell layer, and does not contain a buried A horizon or a lithological discontinuity.

MLRA(s): 149A

Soil Survey Regional Office (SSRO) Responsible:

Depth Class: Very Deep

Drainage Class: Subaqueous (permanently submersed/continuously inundated)

Saturated Hydraulic Conductivity: High

Parent Material: sandy, mixed estuarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 57 degrees F (14 degrees C)

Mean Annual Water Temperature: 57 degrees F (14 degrees C)

TAXONOMIC CLASS: mixed, mesic Sulfic Psammowassents

TYPICAL PEDON: Duvall Creek sand on a southeast flowing wave-built terrace landform with less than 3 percent slope under 2.5 meters of estuarine water. (Colors are for moist soils unless otherwise noted).

Ase – 0 to 13 cm; black (N 2.5/0) fine sand; single grain loose; nonfluid; slight petrochemical odor; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary.

Aseg – 13 to 32 cm; dark greenish gray (10Y 3/1) loamy fine sand; single grain loose; nonfluid; 5% distinct (10YR 4/3) iron oxide concentrations; 2% shell fragments by volume; slight petrochemical odor; neutral (pH 6.58), ultra acid (pH 2.87) after 16 weeks; no color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary.

Cseg1 – 32 to 59 cm; greenish gray (5GY 4/1) sand; single grain loose; nonfluid; slight petrochemical odor; strongly acid (pH 5.16), ultra acid (pH 2.49) after 16 weeks; no color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary.

Cseg2 – 59 to 122 cm; dark greenish gray (10Y 3/1) fine sand; single grain loose; nonfluid; strongly acid (pH 5.52), ultra acid (pH 2.53) after 16 weeks; no color reaction with 3% peroxide, slightly effervescent with 30% peroxide; gradual boundary.

Cseg3 – 122 to 165 cm; dark greenish gray (5GY 3/1) sand; single grain loose; nonfluid; no color reaction with 3% peroxide, slightly effervescent with 30% peroxide.

TYPE LOCATION: Anne Arundel County, Maryland; South River, near the mouth of Beard's Creek, 390 m east of Addison Point, 320 northwest of Boyd Point (sampling point T05P10); USGS South River topographic quadrangle; latitude 38.957075 decimal degrees, longitude -76.569842 decimal degrees, UTM Zone 18N WGS 1984; Major Land Resource Area 149A.

RANGE IN CHARACTERISTICS:

Depth to Bedrock: Greater than 200 cm

Depth to Seasonally High Water Table: Permanently Submersed

Depth to Hypersulfidic Materials (incubated pH ≤4.0): 0 to 50 cm

Manner of Failure/Fluidity Class: Nonfluid

Shell Fragments: 0 to 70 percent, by volume, throughout

Soil Reaction: Strongly Acid to Neutral; Oxidized Reaction: Ultra Acid

Salinity Range is 3 to 16 (ppt)

Tidal Range is 0 to 2 feet (0 to 0.6 meters)

Water Depth is 0 to 2.5 meters

Buried shell layers may be present in these soils

Up to 12% glauconite by weight in the fine-earth fraction

RANGE OF INDIVIDUAL HORIZONS:

Ase, Aseg, or Ag horizon:

Color – hue of N, 2.5Y, 10Y, or 5GY; value of 2.5, 3, or 4; chroma of 0, 1, or2

Texture – sand, fine sand, loamy sand, loamy fine sand, sandy loam, fine sandy loam,

loam, or silt loam

Consistence – nonfluid through very fluid

AC, AC'b, or ACg horizon (if present):

Color – hue of 5GY; value of 2.5, 3, or 4; chroma of 1

Texture – sand, loamy sand, sandy loam

Consistence – nonfluid

Up to 70% shell fragments in this horizon

Cseg, Cg, or C'seg horizon:

Color – N, 10Y, 5GY, 10GY, or 5G; value of 2.5, 3, or 4; chroma of 0 or 1

Texture – sand, fine sand, loamy sand, loamy fine sand, sandy loam, fine sandy loam, loam, silt loam

Consistence – nonfluid through very fluid

COMPETING SERIES:

Nagunt series – contains Buried A horizons; mapped on washover fan flat landforms in MLRA 144A and 149B.

GEOGRAPHIC SETTING:

Landscape: Northern Coastal Plain Subestuaries

Landform: Wave-Built Terraces

Parent Material: sandy, mixed estuarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 50 to 59 degrees F (10 to 15 degrees C)

Mean Annual Water Temperature: 52 to 58 degrees F (11 to 14 degrees C)

Bathymetry: 0 to 8 feet (0 to 2.5 meters)

Water Regime: Tidal; 0 to 2 feet (0 to 0.6 meters)

Water Salinity Range: 3 to 16 ppt

GEOGRAPHICALLY ASSOCIATED SOILS:

Broad Creek soils – mapped on Tidal Creek Channel landforms; composed of Holocene fluid fine material; includes hypersulfidic materials and a buried A horizon.

Cornballer soils – mapped on Estuarine Channel and Mainland Cove landforms; composed of Holocene fluid fine material; contains hypersulfidic materials.

Glebe Bay soils – mapped on Submerged Shoal/Saddle landforms; composed of Holocene sandy material overlying Tertiary material; contains hypersulfidic materials.

Long Point soils – mapped on Submerged Tidal Marsh landforms; composed of Holocene sandy material and hemic organic material overlying a relatively intact paleosol; contains hypersulfidic materials.

Overboard soils – mapped on Tidal Creek Platform landforms; composed of Holocene fluid fine material overlying Tertiary material; includes hypersulfidic materials and a buried A horizon

South River soils – mapped on Wave-Cut Platform landforms; composed of Holocene sandy material overlying Tertiary material; has glauconitic mineralogy, hypersulfidic materials, and horizons with chroma 3 or more between 15 and 100 cm.

DRAINAGE AND HYDRAULIC CONDUCTIVITY:

Drainage Class: Subaqueous

Saturated Hydraulic Conductivity: High

Soil Moisture Regime: Peraquic

Soil is permanently submerged with salt or brackish water with a range of 3 to 16 ppt. The presence of hypersulfidic materials within 50 cm of the soil surface puts these soils at risk for potential acid sulfate soil formation if they are dredged and exposed to air.

USE AND VEGETATION:

Major Uses: Most areas of this soil are used for recreational fishing, swimming, and boating. Commercial uses include shell fishing and aquaculture (The upper part of South River (starting at Glebe Bay) is an oyster sanctuary).

Dominant Vegetation: Benthic fauna such as clams, blue crabs, and oysters are associated with this soil. Eelgrass (*Zostera marina*), sea lettuce (*Ulva sp.*), and horned pondweed (*Zannichellia palustris*) may occur on these soils.

DISTRIBUTION AND EXTENT: Northern Atlantic Coastal Plain subestuaries of the western portion of Chesapeake Bay (Maryland). MLRA 149A. This series is of small extent.

SOIL SURVEY REGIONAL OFFICE (SSRO) RESPONSIBLE:

SERIES ESTABLISHED: Anne Arundel County, Maryland, 2021.

REMARKS: This subaqueous soil series is named for Duvall Creek, a feature of South River. Areas of Duvall Creek soils were formerly included with water.

Diagnostic horizons and other diagnostic soil characteristics recognized in this pedon are:

Ochric epipedon – the zone from 0 to 32 cm

Peraquic feature – the zone from 0 to 165 cm is permanently saturated

Hypersulfidic materials – the zone from 0 to 165 cm

Haplic feature – the zone from 0 to 165 cm is nonfluid (n-value < 0.7)

This soil sometimes includes a buried shell layer (up to 70% shell fragments by volume).

This soil contains 8–12% glauconite (pellets and clay-sized) in the fine-earth fraction.

LOCATION GLEBE BAY MD

Tentative Series

CEP

01/2021

GLEBE BAY SERIES

Series proposed for soils found on Submerged Shoal/Saddle landforms in South River, Md. These soils were mapped as Rhode River, but differences in PSFC, mineralogy, presence of hypersulfidic materials, and presence of jarosite justified a new proposed series.

MLRA(s): 149A

Soil Survey Regional Office (SSRO) Responsible:

Depth Class: Deep

Drainage Class: Subaqueous (permanently submersed/continuously inundated)

Saturated Hydraulic Conductivity: High

Parent Material: sandy, mixed estuarine deposits over sandy, glauconitic fluviomarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 57 degrees F (14 degrees C)

Mean Annual Water Temperature: 57 degrees F (14 degrees C)

TAXONOMIC CLASS: sandy, glauconitic, nonacid, mesic Haplic Sulfiwassents

TYPICAL PEDON: Glebe Bay sand on a permanently submersed shoal or saddle with 1 percent slope under 1 meter of estuarine water in South River. (Colors are for moist soil unless otherwise stated).

Aseg – 0 to 10 cm; greenish gray (10Y 4/1) sand; structureless single grain; nonfluid; 1 percent shell fragments by volume; color change with 3% peroxide, strongly effervescent with 30% peroxide; clear boundary

Ase – 10 to 24 cm; greenish black (10Y 2.5/1) sand; structureless single grain; nonfluid; 20 percent shell fragments by volume; color change with 3% peroxide, strongly effervescent with 30% peroxide; clear boundary

2Btgb1 – 24 to 38 cm; (2.5Y 5/2) sand; structureless single grain; nonfluid; clay nodules (5YR 5/4); 5 percent gravels by volume; no color change with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary

2Btgb2 – 38 to 65 cm; (10Y 5/2) sand; structureless single grain; nonfluid; clay nodules; no color change with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary

2Btb1 – 65 to 79 cm; (5Y 5/3) sand; structureless single grain; nonfluid; clay films and clay nodules; no color reaction with 3% peroxide, non-effervescent with 30% peroxide; clear boundary

2Btb2 – 79 to 105 cm; (2.5Y 6/4) coarse sandy loam; massive; nonfluid; (5YR 6/3) iron oxide concentrations; clay nodules; 10 percent gravels by volume, 1 percent cobbles by volume; no color reaction with 3% peroxide, non-effervescent with 30% peroxide; clear boundary

2BCtb – 105 to 119 cm; (5Y 5/3) sandy loam; massive; nonfluid; no color change with 3% peroxide, non-effervescent with 30% peroxide; clear boundary

2BCtgb – 119 to 147 cm; (10Y 5/2) sandy loam; massive; nonfluid; 5 percent prominent (5YR 3/3) iron oxide concentrations, 5 percent prominent (5YR 4/6) iron oxide concentrations; no color reaction with 3% peroxide, non-effervescent with 30% peroxide

TYPE LOCATION: Anne Arundel County, Maryland; South River, Glebe Bay, 500 m south of Larrimore Point (sampling location T03P04); USGS South River topographic quadrangle; latitude 38.931977 decimal degrees, longitude -76.537778 decimal degrees, UTM Zone 18N WGS 1984; Major Land Resource Area 149A.

RANGE IN CHARACTERISTICS:

Depth to Bedrock: Greater than 200 cm

Depth to Seasonally High Water Table: Permanently Submersed

Depth to Lithological Discontinuity: 24 cm

Depth to Hypersulfidic Materials (incubated pH $\leq$4.0): 0 to 50 cm

Manner of Failure/Fluidity Class: Nonfluid

Shell Fragments: 0 to 20 percent by volume throughout

Soil Reaction: Extremely Acid (oxidized reaction)

Salinity Range is 3 to 16 (ppt)

Tidal Range is 0 to 2 feet (0 to 0.6 meters)

Water Depth is 0 to 1 meters

Up to 22% glauconite by weight in the fine-earth fraction

RANGE OF INDIVIDUAL HORIZONS:

Aseg/Ase horizon:

Color – hue of 10Y; value of 2.5 or 4; chroma of 1

Texture – sand or loamy sand

Consistence – nonfluid

2Btgb/2Btb horizon:

Color – hue of 2.5Y, 5Y, or 10Y; value of 5 or 6; chroma of 2, 3, or 4

Texture – sand, loamy sand, coarse sandy loam, or coarse sandy clay loam

Consistence – nonfluid

2BCtb/2BCtgb horizon:

Color – hue of 5Y or 10Y; value of 5; chroma of 2 or 3

Texture – loamy sand or sandy loam

Consistence – nonfluid

COMPETING SERIES:

Anguilla soils – mapped on Mainland Cove and Submerged Mainland Beach landforms in coastal lagoons (MLRAs 144A and 149B); do not contain an argillic horizon

GEOGRAPHIC SETTING:

Landscape: Northern Coastal Plain Subestuaries

Landform: Submerged Shoal/Saddle

Parent Material: sandy, mixed estuarine deposits over sandy, mixed fluviomarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 50 to 59 degrees F (10 to 15 degrees C)

Mean Annual Water Temperature: 52 to 58 degrees F (11 to 14 degrees C)

Bathymetry: 0 to 3 feet (0 to 1 meters)

Water Regime: Tidal; 0 to 2 feet (0 to 0.6 meters)

Water Salinity Range: 3 to 16 ppt

GEOGRAPHICALLY ASSOCIATED SOILS:

Broad Creek soils – mapped on Tidal Creek Channel landforms; composed of Holocene fluid fine material; includes hypersulfidic materials and a buried A horizon.

Cornballer soils – mapped on Estuarine Channel and Mainland Cove landforms; composed of Holocene fluid fine material; contains hypersulfidic materials.

Duvall Creek soils – mapped on Wave-Built Terrace landforms; composed of Holocene sandy material; includes hypersulfidic materials and a buried shell layer.

Long Point soils – mapped on Submerged Tidal Marsh landforms; composed of Holocene sandy material and hemic organic material overlying a relatively intact paleosol; contains hypersulfidic materials.

Overboard soils – mapped on Tidal Creek Platform landforms; composed of Holocene fluid fine material overlying Tertiary material; includes hypersulfidic materials and a buried A horizon

South River soils – mapped on Wave-Cut Platform landforms; composed of Holocene sandy material overlying Tertiary material; has glauconitic mineralogy, hypersulfidic materials, and horizons with chroma 3 or more between 15 and 100 cm.

DRAINAGE AND HYDRAULIC CONDUCTIVITY:

Drainage Class: Subaqueous

Saturated Hydraulic Conductivity: High

Soil Moisture Regime: Peraquic

Soil is permanently submerged with salt or brackish water with a range of 3 to 16 ppt. The presence of hypersulfidic materials within 50 cm of the soil surface puts these soils at risk for potential acid sulfate soil formation if they are dredged and exposed to air.

USE AND VEGETATION:

Major Uses: Most areas of this soil are used for recreational fishing, swimming, and boating. Commercial uses include shell fishing and aquaculture (The upper part of South River (starting at Glebe Bay) is an oyster sanctuary).

Dominant Vegetation: Benthic fauna such as clams, blue crabs, and oysters are associated with this soil. Eelgrass (*Zostera marina*), sea lettuce (*Ulva sp.*), and horned pondweed (*Zannichellia palustris*) may occur on these soils.

DISTRIBUTION AND EXTENT: Northern Atlantic Coastal Plain subestuaries of the western portion of Chesapeake Bay (Maryland). MLRA 149A. This series is of small extent.

SOIL SURVEY REGIONAL OFFICE (SSRO) RESPONSIBLE:

SERIES ESTABLISHED: Anne Arundel County, Maryland, 2021.

REMARKS: This subaqueous soil series is named for Glebe Bay, a feature of South River. Areas of Glebe Bay soils were formerly included with water.

Diagnostic horizons and other diagnostic soil characteristics recognized in this pedon are:

Ochric epipedon – the zone from 0 to 24 cm (Aseg and Ase horizons)

Peraquic feature – the zone from 0 to 147 cm is permanently saturated

Lithological discontinuity – pre-Holocene contact (Tertiary-aged marine deposits of the Aquia formation); the zone from 24 to 147 cm (2Btgb1, 2Btgb2, 2Btb1, 2Btb2, 2BCtb, 2BCtgb horizons)

Argillic horizon – the zone from 24 to 105 cm (2Btgb1, 2Btgb2, 2Btb1, 2Btb2 horizons); feature developed before permanent submergence

Hypersulfidic materials – the zone from 0 to 24 cm

This soil contains up to 22% glauconite (pellets) in the fine-earth fraction

LOCATION LONG POINT   MD

Tentative Series

CEP

01/2021

LONG POINT SERIES

Series proposed for the soils found on Submerged Tidal Marsh landforms in South River, Md. These soils are composed of a thin mantle of Holocene sand and a horizon of hemic organic material overlying a relatively intact paleosol profile. Submerged Tidal Marsh landforms were mapped at Fox Creek or Muddy Creek, but the observed soils were not Wassists, nor did they have buried organic horizons, so a new proposed series was justified.

MLRA(s): 149A

Soil Survey Regional Office (SSRO) Responsible:

Depth Class: Deep

Drainage Class: Subaqueous (permanently submersed/continuously inundated)

Saturated Hydraulic Conductivity: Low to High

Parent Material: fine-loamy, mixed estuarine deposits and herbaceous organic material over fine-loamy, glauconitic fluviomarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 57 degrees F (14 degrees C)

Mean Annual Water Temperature: 57 degrees F (14 degrees C)

TAXONOMIC CLASS: fine-loamy, glauconitic, nonacid, mesic Typic Sulfiwassents

TYPICAL PEDON: Long Point fine sandy loam on a submerged tidal marsh landform with 1 percent slope under 0.5 meters of estuarine water in South River. (Colors are for moist colors unless otherwise stated).

Ase – 0 to 7 cm; greenish black (10Y 2.5/1) mucky loamy sand; single grain, loose; nonfluid; 20% organic fragments; strong hydrogen sulfide odor; color change with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary

Oe – 7 to 27 cm; reddish black (7.5YR 2.5/2) mucky peat; hemic soil material; 60% organic fragments; strong hydrogen sulfide odor; slightly alkaline (pH 7.37), strongly acid (pH 5.49) after 16 weeks; no color reaction with 3% peroxide, non-effervescent with 30% peroxide; clear boundary

2A'se – 27 to 46 cm; greenish black (10Y 2.5/1) mucky fine sandy loam; massive; moderately fluid; 15% organic fragments; strong hydrogen sulfide odor; neutral (pH 7.34), extremely acid (pH 4.01) after 16 weeks; no color reaction with 3% peroxide, non-effervescent with 30% peroxide; clear boundary

2Eseg – 46 to 55 cm; (10Y 5/1) fine sandy loam; massive; nonfluid; 15% organic fragments; slight hydrogen sulfide odor; no color reaction with 3% peroxide, very slightly effervescent with 30% peroxide; gradual boundary

2Btseg1 – 55 to 69 cm; (5GY 4/1) sandy clay loam; massive; slightly fluid; <2% distinct iron oxide concentrations; 10% organic fragments; slight hydrogen sulfide odor; no color reaction with 3% peroxide, very slightly effervescent with 30% peroxide; clear boundary

2Btseg2 – 69 to 86 cm; (5G 4/1) clay; massive; nonfluid; 5% distinct (10YR 5/3) iron oxide concentrations; 5% organic fragments; moderately alkaline (pH 7.91), strongly acid (pH 5.46) after 16 weeks; no color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary

2Btseg3 – 86 to 117 cm; (10Y 4/2) sandy clay; massive; nonfluid; <2% distinct iron oxide concentrations; 5% gravels by volume; no color reaction with 3% peroxide, strongly effervescent with 30% peroxide

TYPE LOCATION: Anne Arundel County, Maryland; South River, Selby Bay, behind Long Point (sampling point SP03); USGS South River topographic quadrangle; latitude 38.914663 decimal degrees, longitude -76.509447 decimal degrees, UTM Zone 18N WGS 1984; Major Land Resource Area 149A.

RANGE IN CHARACTERISTICS:

Depth to Bedrock: Greater than 200 cm

Depth to Seasonally High Water Table: Permanently Submersed

Depth to Lithological Discontinuity: 21 to 28 cm

Depth to Hypersulfidic Materials (incubated pH $\leq$4.0): 0 to 50 cm

Manner of Failure/Fluidity Class: Nonfluid to Moderately Fluid

Shell Fragments: 0 to 2 percent by volume throughout

Soil Reaction: Neutral to Moderately Akaline; oxidized reaction: Strongly Acid to Extremely Acid

Salinity Range is 3 to 16 (ppt)

Tidal Range is 0 to 2 feet (0 to 0.6 meters)

Water Depth is 0 to 0.5 meters

Up to 26% glauconite by weight in the fine-earth fraction

RANGE OF INDIVIDUAL HORIZONS:

Ase or A horizon:

Color – hue of 5Y or 10Y; value of 2.5 or 3; chroma of 1 or 2

Texture – sand, mucky loamy sand, mucky sandy loam

Consistence – nonfluid, slightly fluid

Oe or Oase horizon:

Color – hue of 7.5YR; value of 2.5; chroma of 2

Texture – mucky peat (hemic soil material)

Consistence – nonfluid

ABse or ABseg horizon (if present):

Color – hue of 2.5Y or 10Y; value of 4; chroma of 1

Texture – sandy loam

Consistence – nonfluid, slightly fluid

2A'se horizon:

Color – hue of 10Y; value of 2.5; chroma of 1

Texture – mucky fine sandy loam

Consistence – moderately fluid

2Eseg horizon:

Color – hue of 10Y; value of 5; chroma of 1

Texture – fine sandy loam

Consistence – nonfluid

2Btseg, 2Btg, or 2Btsegb horizon:

Color – hue of 10Y, 5GY, 10GY, or 5G; value of 3 or 4; chroma of 1 or 2

Texture – sandy clay loam, sandy clay, or clay

Consistence – nonfluid to moderately fluid

BCt or BCtg horizon (if present):

Color – hue of 5Y or 10Y; value of 4; chroma of 2 or 3

Texture – sandy clay

Consistence – nonfluid

2CBsegb horizon (if present):

Color – hue of 10YR or 10GY; value of 3 or 4; chroma of 1 or 2

Texture – loamy sand or sandy loam

Consistence - nonfluid

COMPETING SERIES: None

GEOGRAPHIC SETTING:

Landscape: Northern Coastal Plain Subestuaries

Landform: Submerged Tidal Marsh

Parent Material: fine-loamy, mixed estuarine deposits and herbaceous organic material over fine-loamy, glauconitic fluviomarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 50 to 59 degrees F (10 to 15 degrees C)

Mean Annual Water Temperature: 52 to 58 degrees F (11 to 14 degrees C)

Bathymetry: 0 to 2 feet (0 to 0.5 meters)

Water Regime: Tidal; 0 to 2 feet (0 to 0.6 meters)

Water Salinity Range: 3 to 16 ppt

GEOGRAPHICALLY ASSOCIATED SOILS:

Broad Creek soils – mapped on Tidal Creek Channel landforms; composed of Holocene fluid fine material; includes hypersulfidic materials and a buried A horizon.

Cornballer soils – mapped on Estuarine Channel and Mainland Cove landforms; composed of Holocene fluid fine material; contains hypersulfidic materials.

Duvall Creek soils – mapped on Wave-Built Terrace landforms; composed of Holocene sandy material; includes hypersulfidic materials and a buried shell layer.

Glebe Bay soils – mapped on Submerged Shoal/Saddle landforms; composed of Holocene sandy material overlying Tertiary material; contains hypersulfidic materials.

Overboard soils – mapped on Tidal Creek Platform landforms; composed of Holocene fluid fine material overlying Tertiary material; includes hypersulfidic materials and a buried A horizon

South River soils – mapped on Wave-Cut Platform landforms; composed of Holocene sandy material overlying Tertiary material; has glauconitic mineralogy, hypersulfidic materials, and horizons with chroma 3 or more between 15 and 100 cm.

DRAINAGE AND HYDRAULIC CONDUCTIVITY:

Drainage Class: Subaqueous

Saturated Hydraulic Conductivity: Low to High

Soil Moisture Regime: Peraquic

Soil is permanently submerged with salt or brackish water with a range of 3 to 16 ppt.

The presence of hypersulfidic materials within 50 cm of the soil surface puts these soils at risk for potential acid sulfate soil formation if they are dredged and exposed to air.

USE AND VEGETATION:

Major Uses: Most areas of this soil are used for recreational fishing, swimming, and boating. Commercial uses include shell fishing and aquaculture (The upper part of South River (starting at Glebe Bay) is an oyster sanctuary).

Dominant Vegetation: Benthic fauna such as clams, blue crabs, and oysters are associated with this soil. Eelgrass (*Zostera marina*), sea lettuce (*Ulva sp.*), and horned pondweed (*Zannichellia palustris*) may occur on these soils.

DISTRIBUTION AND EXTENT: Northern Atlantic Coastal Plain subestuaries of the western portion of Chesapeake Bay (Maryland). MLRA 149A. This series is of small extent.

SOIL SURVEY REGIONAL OFFICE (SSRO) RESPONSIBLE:

SERIES ESTABLISHED: Anne Arundel County, Maryland, 2021.

REMARKS: This subaqueous soil series is named for Long Point, a feature in South River. Areas of Long Point soils were formerly included with water.

Diagnostic horizons and other diagnostic soil characteristics recognized in this pedon are:

Ochric epipedon – the zone from 0 to 46 cm (Ase, Oe, and 2A’se horizons)

Hemic soil material – the zone from 7 to 27 cm (Oe horizon)

Lithological discontinuity – pre-Holocene contact (Tertiary-aged marine deposits of the Aquia formation); the zone from 27 to 117 cm (2A’se, 2Eseg, 2Btseg1, 2Btseg2, 2Btseg3 horizons)

Albic horizon – the zone from 46 to 55 cm

Argillic horizon – the zone from 55 to 117 cm (2Btseg1, 2Btseg2, 2Btseg3 horizons); feature developed before permanent submergence

Hypersulfidic materials – the zone from 0 to 46 cm

Up to 26% glauconite (pellets and clay-sized) by weight in the fine-earth fraction

LOCATION OVERBOARD MD

Tentative Series

CEP

01/2021

OVERBOARD SERIES

Series proposed for the soils found on Tidal Creek Platform landforms in South River. These soils are composed of Holocene fluid fine materials, with a lithological discontinuity and pre-Holocene contact close to 2 m. These landforms were mapped as Contees Wharf or Sellman, but because of differences in PSFC, mineralogy, and presence of hypersulfidic materials, a new proposed series was justified. This proposed series has a buried A horizon (differentiating it from the Cornballer proposed series) and pre-holocene contact (differentiating it from the Broad Creek proposed series).

MLRA(s): 149A

Soil Survey Regional Office (SSRO) Responsible:

Depth Class: Very Deep

Drainage Class: Subaqueous (permanently submersed/continuously inundated)

Saturated Hydraulic Conductivity: Moderately High

Parent Material: fine-loamy, mixed estuarine deposits over fine-loamy, glauconitic fluviomarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 57 degrees F (14 degrees C)

Mean Annual Water Temperature: 57 degrees F (14 degrees C)

TAXONOMIC CLASS: fine-loamy, glauconitic, nonacid, mesic Fluventic Sulfiwassents

TYPICAL PEDON: Overboard silt loam on a permanently submersed tidal creek platform landform with less than 3 percent slope under 1.5 meters of estuarine water. (Colors are for moist soil unless otherwise stated).

Ase – 0 to 20 cm; black (N 2.5/0) loam; massive; very fluid; slight petrochemical odor; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; gradual boundary

Cseg1 – 20 to 38 cm; greenish black (10Y 2.5/1) loam; massive; very fluid; 1% organic fragments; slight petrochemical odor; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary

Cseg2 – 38 to 50 cm; greenish black (5GY 2.5/1) loam; massive; very fluid; 1% organic fragments; slight petrochemical odor; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; clear boundary

Aseb1 – 50 to 84 cm; black (N 2.5/0) silt loam; massive; very fluid; 1% shell fragments by volume; slight petrochemical odor; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; gradual boundary

Aseb2 – 84 to 123 cm; black (N 2.5/0) loam; massive; moderately fluid; slight petrochemical odor; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; gradual boundary

C'seg – 123 to 176 cm; greenish black (10GY 2.5/1) silt loam; massive; moderately fluid; <1% shell fragments by volume; slight petrochemical odor; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; gradual boundary

2Cg1 – 176 to 226 cm; (5Y 2.5/1) silt loam; massive; slightly fluid; 1% shell fragments by volume; root hairs throughout; no color reaction with 3% peroxide, very slightly effervescent with 30% peroxide; gradual boundary

2Cg2 – 226 to 276 cm; (5Y 2.5/1) silt loam; massive; slightly fluid; root hairs throughout; no color reaction with 3% peroxide, very slightly effervescent with 30% peroxide; gradual boundary

2Cg3 – 276 to 317 cm; (5Y 2.5/1) silt loam; massive; slightly fluid; root hairs throughout; no color reaction with 3% peroxide, very slightly effervescent with 30% peroxide

TYPE LOCATION: Anne Arundel County, Maryland; South River, Broad Creek, 450 m south of marsh at head of creek (sampling point T06P02); USGS South River topographic quadrangle; latitude 38.972474 decimal degrees, longitude -76.575993 decimal degrees, UTM Zone 18N WGS 1984; Major Land Resource Area 149A.

RANGE IN CHARACTERISTICS:

Depth to Bedrock: Greater than 200 cm

Depth to Seasonally High Water Table: Permanently Submersed

Depth to Lithological Discontinuity: 57 to 176 cm

Depth to Hypersulfidic Materials (incubated pH ≤4.0): 0 to 50 cm

Manner of Failure/Fluidity Class: Slightly Fluid to Very Fluid throughout

Shell Fragments: 0 to 10 percent by volume

Soil Reaction: Extremely Acid to Strongly Alkaline; oxidized reaction: Ultra Acid to Extremely Acid

Salinity Range is 3 to 16 (ppt)

Tidal Range is 0 to 2 feet (0 to 0.6 meters)

Water Depth is 0 to 5 feet (0 to 1.5 meters)

Up to 19% glauconite by weight in the fine-earth fraction

RANGE OF INDIVIDUAL HORIZONS:

Ase horizon:

Color – hue of N, 10Y, 5GY, or 10GY; value of 2.5 or 3; chroma of 0 or 1

Texture – sand, loamy sand, fine sandy loam, loam, or clay loam

Consistence – moderately fluid or very fluid

Cseg horizon:

Color – hue of N, 10Y, 5GY, 10GY, 5G, 10G, or 5BG; value of 2.5 or 3; chroma of 0 or 1

Texture – sandy loam, loam, silt loam, or clay loam

Consistence – moderately fluid to very fluid

Aseb horizon:

Color – hue of N; value of 2.5; chroma of 0

Texture – loam or silt loam

Consistence – moderately fluid or very fluid

C'seg horizon:

Color – hue of 10GY; value of 2.5; chroma of 1

Texture – silt loam

Consistence – moderately fluid

2BAb horizon (if present):

Color – hue of 5GY; value of 3; chroma of 1

Texture – loamy sand

Consistence – nonfluid

2Btgb horizon (if present):

Color – hue of 10GY; value of 3; chroma of 1

Texture – fine sandy loam

Consistence – nonfluid

2BCgb horizon (if present):

Color – hue of 5Y or 10Y; value of 5; chroma of 2

Texture – sand

Consistence – nonfluid

2Cg/2C horizon:

Color – hue of 2.5Y or 5Y; value of 2.5 or 5; chroma of 1 or 3

Texture – sand or silt loam

Consistence – nonfluid or slightly fluid

COMPETING SERIES:

Broad Creek soils – mapped on Tidal Creek Channel landforms in South River; contains buried A horizon, but does not have pre-Holocene contact in upper 200 cm

Cornballer soils – mapped on Estuarine Channel and Mainland Cove landforms in South River; does not contain buried A horizon

GEOGRAPHIC SETTING:

Landscape: Northern Coastal Plain Subestuaries

Landform: Tidal Creek Platform

Parent Material: fine-loamy, mixed estuarine deposits over fine-loamy, glauconitic fluviomarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 50 to 59 degrees F (10 to 15 degrees C)

Mean Annual Water Temperature: 52 to 58 degrees F (11 to 14 degrees C)

Bathymetry: 0 to 4 feet (0 to 1.5 meters)

Water Regime: Tidal; 0 to 2 feet (0 to 0.6 meters)

Water Salinity Range: 3 to 16 ppt

GEOGRAPHICALLY ASSOCIATED SOILS:

Broad Creek soils – mapped on Tidal Creek Channel landforms; composed of Holocene fluid fine material; includes hypersulfidic materials and a buried A horizon.

Cornballer soils – mapped on Estuarine Channel and Mainland Cove landforms; composed of Holocene fluid fine material; contains hypersulfidic materials.

Duvall Creek soils – mapped on Wave-Built Terrace landforms; composed of Holocene sandy material; includes hypersulfidic materials and a buried shell layer.

Glebe Bay soils – mapped on Submerged Shoal/Saddle landforms; composed of Holocene sandy material overlying Tertiary material; contains hypersulfidic materials.

Overboard soils – mapped on Tidal Creek Platform landforms; composed of Holocene fluid fine material overlying Tertiary material; includes hypersulfidic materials and a buried A horizon

South River soils – mapped on Wave-Cut Platform landforms; composed of Holocene sandy material overlying Tertiary material; has glauconitic mineralogy, hypersulfidic materials, and horizons with chroma 3 or more between 15 and 100 cm.

DRAINAGE AND HYDRAULIC CONDUCTIVITY:

Drainage Class: Subaqueous

Saturated Hydraulic Conductivity: Moderately High

Soil Moisture Regime: Peraquic

Soil is permanently submerged with salt or brackish water with a range of 3 to 16 ppt. The presence of hypersulfidic materials within 50 cm of the soil surface puts these soils at risk for potential acid sulfate soil formation if they are dredged and exposed to air.

USE AND VEGETATION:

Major Uses: Most areas of this soil are used for recreational fishing, swimming, and boating. Commercial uses include shell fishing and aquaculture (The upper part of South River (starting at Glebe Bay) is an oyster sanctuary).

Dominant Vegetation: Benthic fauna such as clams, blue crabs, and oysters are associated with this soil. Eelgrass (*Zostera marina*), sea lettuce (*Ulva sp.*), and horned pondweed (*Zannichellia palustris*) may occur on these soils.

DISTRIBUTION AND EXTENT: Northern Atlantic Coastal Plain subestuaries of the western portion of Chesapeake Bay (Maryland). MLRA 149A. This series is of small extent.

SOIL SURVEY REGIONAL OFFICE (SSRO) RESPONSIBLE:

SERIES ESTABLISHED: Anne Arundel County, Maryland, 2021.

REMARKS: This subaqueous soil series is named for the fact that CEP fell overboard at the type location of the proposed series. A review of relevant literature indicated that CEP was the first researcher to fall overboard in any of the subaqueous soil surveys in Chesapeake Bay, so this name reflects an original scientific contribution of the South River study.

Areas of Overboard soils were formerly included with water.

Diagnostic horizons and other diagnostic soil characteristics recognized in this pedon are:

Ochric epipedon – the zone from 0 to 20 cm (Ase horizon)

Peraquic feature – the zone from 0 to 317 cm is permanently saturated

Hypersulfidic materials – the zone from 0 to 176 cm

Lithological discontinuity – pre-Holocene contact (Tertiary-aged marine deposits of the Aquia formation); the zone from 176 to 317 cm (2Cg1, 2Cg2, 2Cg3 horizons)

Up to 19% glauconite (pellets and clay-sized) by weight in the fine-earth fraction

LOCATION SOUTH RIVER MD

Tentative Series

CEP

01/2021

SOUTH RIVER SERIES

Series proposed for the soils found on Wave-Cut Platform landforms in South River, Md. These soils were composed of a Holocene-aged, sandy mantle overlying a truncated paleosol. The series is similar in concept to the Rhode River series, which was proposed by Wessel (2020) to capture soils with Holocene sands over tertiary material on Wave-Cut Platform landforms in Rhode River, but it contains hypersulfidic materials.

MLRA(s): 149A

Soil Survey Regional Office (SSRO) Responsible:

Depth Class: Moderately Deep

Drainage Class: Subaqueous (permanently submersed/continuously inundated)

Saturated Hydraulic Conductivity: High

Parent Material: sandy, mixed estuarine deposits over coarse-loamy, glauconitic fluviomarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 57 degrees F (14 degrees C)

Mean Annual Water Temperature: 57 degrees F (14 degrees C)

TAXONOMIC CLASS: coarse-loamy, glauconitic, nonacid, mesic Aeric Sulfiwassents

TYPICAL PEDON: sandy loam on a southwest facing wave-cut platform landform with less than 3 percent slope under 1 meter of estuarine water. (Colors are for moist soils unless otherwise noted).

Ase – 0 to 16 cm; dark greenish gray (10Y 3/1) loamy sand; single grain loose; nonfluid; trace shell fragments; neutral (pH 6.8), netural (pH 6.64) after 16 weeks; color reaction with 3% peroxide, slightly effervescent with 30% peroxide; abrupt boundary.

2BC1 – 16 to 32 cm; (10YR 4/4) sandy loam; massive; nonfluid; 6% prominent (7.5YR 6/8) iron oxide concentrations; neutral (pH 6.74), slightly acid (pH 6.35) after 16 weeks; no color reaction with 3% peroxide, non-effervescent with 30% peroxide; clear boundary.

2BC2 – 32 to 55 cm; (10YR 5/3) sandy loam; massive; nonfluid; 6% prominent (5YR 5/6) iron oxide concentrations; neutral (pH 6.71), slightly acid (pH 6.46) after 16 weeks; no color reaction with 3% peroxide, non-effervescent with 30% peroxide; clear boundary.

2CBg – 55 to 82 cm; (10YR 4/2) sandy loam; massive; nonfluid; neutral (pH 6.58), slightly acid (pH 6.4) after 16 weeks; no color reaction with 3% peroxide, non-effervescent with 30% peroxide.

TYPE LOCATION: Anne Arundel County, Maryland; South River, 630 m southeast of Melvin Point (sampling point T02P08); USGS South River topographic quadrangle; latitude 38.93878 decimal degrees, longitude -76.517349 decimal degrees, UTM Zone 18N WGS 1984; Major Land Resource Area 149A.

RANGE IN CHARACTERISTICS:

Depth to Bedrock: Greater than 200 cm

Depth to Seasonally High Water Table: Permanently submersed

Depth to Lithological Discontinuity: 16 to 74 cm

Depth to Hypersulfidic Materials (incubated pH ≤4.0): 0 to 50 cm

Manner of Failure/Fluidity Class: nonfluid to moderately fluid

Shell Fragments: 0 to 60 percent by volume

Soil Reaction: Very Strongly Acid to Strongly Alkaline; oxidized reaction: Ultra Acid to Moderately Alkaline

Salinity Range is 3 to 16 (ppt)

Tidal Range is 0 to 2 feet (0 to 0.6 meters)

Water Depth is 0 to 13 feet (0 to 4 meters)

Buried shell layers are sometimes present in these soils

Up to 23% glauconite by weight in the fine-earth fraction

RANGE OF INDIVIDUAL HORIZONS:

Ase, Ag, or A horizon:

Color – hue of N, 2.5Y, 5Y, 10Y, 5GY, or 10GY; value of 2.5, 3, 4, or 5; chroma of 0, 1, or 2

Texture – sand, loamy sand, or clay loam

Consistence – nonfluid to moderately fluid

ACg horizon (if present):

Color – hue of 10Y or 5GY; value of 2.5, 3, or 4; chroma of 1 or 2

Texture – sand, fine sand, loamy sand, loamy fine sand, sandy loam, fine sandy loam, or loam

Consistence – nonfluid or slightly fluid

These horizons contain up to 60% shell fragments by volume

2Btseb or 2Btsegb horizon (if present):

Color – hue of 10YR, 5GY, or 5G; value of 3 or 4; chroma of 2

Texture – sandy loam, sandy clay loam, sandy clay, or clay

Consistence – nonfluid or slightly fluid

2BC, 2BCgb, 2BCseb, or 2BCsegb horizon:

Color – hue of 5YR, 10YR, 5Y, 10Y, 5GY, or 10GY; value of 3, 4, 5, or 6; chroma of 1, 2, 3, 4, or 6

Texture – loamy coarse sand, loamy sand, coarse sandy loam, sandy loam, fine sandy loam, sandy clay loam, clay loam, sandy clay, or clay

Consistence – nonfluid

2CBg horizon:

Color – hue of 10YR or 5GY; value of 4 or 6; chroma of 1 or 2

Texture – sandy loam, clay loam, or clay

Consistence - nonfluid

COMPETING SERIES: None

GEOGRAPHIC SETTING:

Landscape: Northern Coastal Plain Subestuaries

Landform: Wave-Cut Platform

Parent Material: sandy, mixed estuarine deposits over coarse-loamy, glauconitic fluviomarine deposits

Slope: 0 to 3 percent

Mean Annual Air Temperature: 50 to 59 degrees F (10 to 15 degrees C)

Mean Annual Water Temperature: 52 to 58 degrees F (11 to 14 degrees C)

Bathymetry: 0 to 13 feet (0 to 4 meters)

Water Regime: Tidal; 0 to 2 feet (0 to 0.6 meters)

Water Salinity Range: 3 to 16 ppt

GEOGRAPHICALLY ASSOCIATED SOILS:

Broad Creek soils – mapped on Tidal Creek Channel landforms; composed of Holocene fluid fine material; includes hypersulfidic materials and a buried A horizon.

Cornballer soils – mapped on Estuarine Channel and Mainland Cove landforms; composed of Holocene fluid fine material; contains hypersulfidic materials.

Duvall Creek soils – mapped on Wave-Built Terrace landforms; composed of Holocene sandy material; includes hypersulfidic materials and a buried shell layer.

Glebe Bay soils – mapped on Submerged Shoal/Saddle landforms; composed of Holocene sandy material overlying Tertiary material; contains hypersulfidic materials.

Long Point soils – mapped on Submerged Tidal Marsh landforms; composed of Holocene sandy material and hemic organic material overlying a relatively intact paleosol; contains hypersulfidic materials.

Overboard soils – mapped on Tidal Creek Platform landforms; composed of Holocene fluid fine material overlying Tertiary material; includes hypersulfidic materials and a buried A horizon

DRAINAGE AND HYDRAULIC CONDUCTIVITY:

Drainage Class: Subaqueous

Saturated Hydraulic Conductivity: High

Soil Moisture Regime: Peraquic

Soil is permanently submerged with salt or brackish water with a range of 3 to 16 ppt. The presence of hypersulfidic materials within 50 cm of the soil surface puts these soils at risk for potential acid sulfate soil formation if they are dredged and exposed to air.

USE AND VEGETATION:

Major Uses: Most areas of this soil are used for recreational fishing, swimming, and boating. Commercial uses include shell fishing and aquaculture (The upper part of South River (starting at Glebe Bay) is an oyster sanctuary).

Dominant Vegetation: Benthic fauna such as clams, blue crabs, and oysters are associated with this soil. Eelgrass (*Zostera marina*), sea lettuce (*Ulva sp.*), and horned pondweed (*Zannichellia palustris*) may occur on these soils.

DISTRIBUTION AND EXTENT: Northern Atlantic Coastal Plain subestuaries of the western portion of Chesapeake Bay (Maryland). MLRA 149A. This series is of small extent.

SOIL SURVEY REGIONAL OFFICE (SSRO) RESPONSIBLE:

SERIES ESTABLISHED: Anne Arundel County, Maryland, 2021.

REMARKS: This subaqueous soil series is named for South River, since it exemplifies the complex pedogenic history of the subestuary. South River soils were formerly included with water.

Diagnostic horizons and other diagnostic soil characteristics recognized in this pedon are:

Ochric epipedon – the zone from 0 to 16 cm (Ase horizon)

Peraquic feature – the zone from 0 to 82 cm is permanently saturated

Hypersulfidic materials – found in the upper 50 cm

Lithological discontinuity – pre-Holocene contact (Tertiary-aged marine deposits of the Aquia formation); the zone from 16 to 82 cm

Argillic horizon is sometimes present in the Tertiary-aged materials; these features developed before permanent submergence.

Buried shell layers are sometimes present in the Holocene-aged materials

Up to 23% glauconite (pellets and clay-sized) by weight in the fine-earth fraction

Appendix G. Halinity Measurement Method Proposal

This method is a modification of method 4.6.5 from Soil Survey Field and Laboratory Methods Manual. It was included in a proposal presented to the Coastal Zone Soil Survey. The method is applicable to coastal areas, where highly soluble salts constitute the majority of the solutes.

Electrical Conductivity by 1:5 Aqueous Dilution by Volume

Prepared by C. Evan Park and M. C. Rabenhorst

23 June 2020

Summary of Method

This methodology is a modification of method 4.6.5 found in Soil Survey Field and Laboratory Methods Manual (version 2, issued 2014). A fresh (or refrigerated) moist soil sample is mixed with 5 parts distilled water (by volume). The mixture is shaken and left to equilibrate. $EC_{1:5}$ is determined for unfiltered supernatant and reported as dS m-1. At the same time that conductivity is measured, a duplicate sample is weighed, then dried in the oven and weighed again to determine volumetric water content. A dilution factor can then be calculated in order to more accurately determine the porewater EC by applying the dilution factor to the measured $EC_{1:5.}$

Equipment

1. Container with water tight lid, 100-ml
2. Oven-safe screw-top container, 100 mL (for moisture content sample)
3. EC meter, pocket-type or hand-held, or lab grade

4. Balance (accurate to hundredths of a gram)

Reagents

1. Distilled water

2. Potassium chloride (KCl), 0.010 *N* for EC meter calibration. Dry KCl overnight in oven (110 °C). Dissolve 0.7456 g of KCl in distilled water and bring to 1-L volume. Conductivity at 25 °C is 1.4 dS m-1. *Alternatively*, KCl calibration solutions, commercially prepared (e.g., 20-ml calibration solution packets).

3. Material Safety Data Sheets (MSDS)

Procedure

1:5 EC Measurement

1. Calibrate EC meter using calibration solution.

2. Measure a known volume of moist sample into an appropriately sized plastic bottle[2] with lid providing a water tight seal. (Samples should have been refrigerated if they were collected 1 or 2 days prior to the testing. They should have been frozen if they were stored longer.) Five mL could be measured conveniently using a teaspoon (actually 4.93 mL) or 15 mL could be measured conveniently using a tablespoon (actually 14.79 mL). These readily available utensils should make it easy to collect the replicate samples needed (see step 7 below).

[2] If a teaspoon measure is used, a 50 to 100 mL container will suffice. If a tablespoon measure is used, then a 150-250 mL container will be needed.

3. Using a graduated cylinder, measure a volume of distilled water 5 times the volume of soil and add to the container with the soil. Seal the container and shake vigorously for 10s. After 1 minute, re-shake for another 10s.

4. Allow the mixture to settle. Coarse textured samples will settle in as little as 15 min. Fine-textured samples and those that have a high content of organic matter may require longer.

5. Immerse tip of calibrated hand-held EC meter into the overlying solution, being careful not to immerse the electrode into the soil phase that has settled out.

6. Allow the reading to stabilize. Read and record $EC_{1:5}$ of the unfiltered supernatant.

Moisture Content Measurement

7. At the same time that conductivity is measured, a duplicate moist sample of equal volume should be placed into a pre-weighed container to determine moisture content.

8. Weigh the duplicate moist sample immediately and record the "wet weight", then place it in an oven overnight to dry. (Note: If this procedure is done in the field, the container with the wet sample must be sealed securely to prevent loss of sample or evaporative water loss. Measuring of wet and dry weights can then be done upon returning from the field.)

9. Weigh the oven-dry duplicate sample and record the "oven-dry weight"

Porewater EC Calculation

10. The volume of water originally present in the soil sample (Wv) used in the 1:5 dilution is equal to the weight of the water lost from the duplicate sample during drying (Wv = water weight = wet weight – dry weight).

11. Dilution factor[3] = (Wv + volume of water added) ÷ Wv

12. Multiply the measured $EC_{1:5}$ value by the dilution factor to determine the porewater EC.

13. The halinity (or practical salinity) of the porewater can then be calculated by applying the appropriate conversion factor.

[3] Typically the dilution factor will fall within the range of 10 and 20 but could range between 7 and 40

Appendix H. Electrical Conductivity and Halinity Data

A	B	C	D	E	F	G	H	I	J	K	L	M
Pedon	Horizon	Bottom Depth (cm)	Wet Wt (g)	Dry Wt (g)	Volume of water in sample (mL)	Gravimetric Water Content (g water/g soil)	Bulk Density (g soil/cm^3 soil)	1:5 EC (dS/m)	Dilution Factor	Porewater EC (dS/m)	Porewater Halinity (ppt)	pH
					D – E (equivalent to water wt (g))	E/F	E/15 mL		(F + 75 mL)/F	I * J	If K<5, K * 0.64 Else, K * 0.8	
T01P01	Ase	44	20.51	8.87	11.64	1.31	0.59	1.608	7.4	12.0	9.6	8.08
T01P01	Cseg1	79	19.85	8.28	11.57	1.40	0.55	1.623	7.5	12.1	9.7	8.04
T01P01	Cseg2	124	20.81	8.47	12.34	1.46	0.56	0.829	7.1	5.9	4.7	7.53
T01P01	Cseg3	156	20.8	9.34	11.46	1.23	0.62	0.413	7.5	3.1	2.0	7.4
T01P02	Ase	20	27.15	20.95	6.2	0.30	1.40	1.064	13.1	13.9	11.1	8.14
T01P02	Cseg	40	26.69	20.82	5.87	0.28	1.39	0.967	13.8	13.3	10.7	8.1
T01P02	2BCb	56	27.72	22.06	5.66	0.26	1.47	0.898	14.3	12.8	10.2	6.56
T01P02	2CBb	78	30.27	23.1	7.17	0.31	1.54	1.112	11.5	12.7	10.2	6.05
T01P03	Ase	18	23.43	12.74	10.69	0.84	0.85	1.841	8.0	14.8	11.8	6.85
T01P03	Cseg1	43	23.77	12.31	11.46	0.93	0.82	1.541	7.5	11.6	9.3	7.74
T01P03	Cseg2	56	22.27	10.79	11.48	1.06	0.72	1.96	7.5	14.8	11.8	7.73
T01P05	Ase	4	25.19	16.38	8.81	0.54	1.09	1.603	9.5	15.2	12.2	7.43
T01P05	Ag	30	25.39	16.71	8.68	0.52	1.11	1.578	9.6	15.2	12.2	7.82
T01P05	Cg1	47	28.11	22.2	5.91	0.27	1.48	1.36	13.7	18.6	14.9	7.67
T01P05	Cg2	78	28.57	22.69	5.88	0.26	1.51	1.582	13.8	21.8	17.4	7.77
T01P05	2Btb	99	26.77	19.69	7.08	0.36	1.31	1.287	11.6	14.9	11.9	7.5
T01P05	2BCb	121	25.2	20.36	4.84	0.24	1.36	1.312	16.5	21.6	17.3	7.16
T01P05	2CBgb1	140	26.84	21.55	5.29	0.25	1.44	1.278	15.2	19.4	15.5	6.68
T01P05	2CBgb2	164	25.41	20.41	5	0.24	1.36	1.41	16.0	22.6	18.0	5.72
T01P05	2CBgb3	181	26.75	21.55	5.2	0.24	1.44	1.104	15.4	17.0	13.6	6.03
T01P07	Aseg	6	26.23	17.99	8.24	0.46	1.20	1.426	10.1	14.4	11.5	7.39
T01P07	Ase	21	25.6	17.87	7.73	0.43	1.19	1.374	10.7	14.7	11.8	8.29

T01P07	Cseg1	57	20.96	12.25	8.71	0.71	0.82	0.336	9.6	3.2	2.1	8.26
T01P07	Cseg2	98	22.03	13.7	8.33	0.61	0.91	1.695	10.0	17.0	13.6	7.9
T01P07	Agb	122	28.23	22.18	6.05	0.27	1.48	1.201	13.4	16.1	12.9	7.7
T01P07	2Btgb	139	28.5	21.82	6.68	0.31	1.45	0.949	12.2	11.6	9.3	8.38
T01P07	2Cg1	143	27.15	19.96	7.19	0.36	1.33	1.314	11.4	15.0	12.0	7.93
T01P07	2Cg2	157	21.69	12.58	9.11	0.72	0.84	1.23	9.2	11.4	9.1	7.55
T01P09	A	18	27.81	22.68	5.13	0.23	1.51	0.687	15.6	10.7	8.6	8.25
T01P09	2Btsegb1	49	27.65	20.74	6.91	0.33	1.38	0.395	11.9	4.7	3.0	7.75
T01P09	2Btsegb2	71	29.48	23.22	6.26	0.27	1.55	0.24	13.0	3.1	2.0	7.2
T01P09	2BCsegb	97	28.02	23.1	4.92	0.21	1.54	0.111	16.2	1.8	1.2	6.79
T02P01	Ase	18	26.34	20.29	6.05	0.30	1.35	0.904	13.4	12.1	9.7	7.62
T02P01	Cseg1	35	28.09	21.08	7.01	0.33	1.41	1.208	11.7	14.1	11.3	8.15
T02P01	Cseg2	50	26.43	17.6	8.83	0.50	1.17	1.291	9.5	12.3	9.8	8.37
T02P01	Cseg3	70	20.76	11.54	9.22	0.80	0.77	1.523	9.1	13.9	11.1	8.02
T02P01	Cseg4	92	21.58	11.57	10.01	0.87	0.77	1.725	8.5	14.6	11.7	7.87
T02P03	Aseg	20	25.49	20.24	5.25	0.26	1.35	1.108	15.3	16.9	13.5	7.6
T02P03	AC	98	24.79	20.08	4.71	0.23	1.34	1.283	16.9	21.7	17.4	7.95
T02P03	Cseg1	148	27.37	21.77	5.6	0.26	1.45	1.497	14.4	21.5	17.2	8.02
T02P03	Cseg2	198	25.85	20.3	5.55	0.27	1.35	1.688	14.5	24.5	19.6	7.9
T02P03	Cseg3	248	26.88	20.61	6.27	0.30	1.37	1.647	13.0	21.3	17.1	8.41
T02P03	Cseg4	268	27.84	21.18	6.66	0.31	1.41	1.852	12.3	22.7	18.2	7.84
T02P05	Ase1	23	19.74	8.56	11.18	1.31	0.57	1.977	7.7	15.2	12.2	7.86
T02P05	Ase2	58	19.61	7.97	11.64	1.46	0.53	2.15	7.4	16.0	12.8	7.85
T02P05	Cseg1	89	19.58	8.63	10.95	1.27	0.58	1.806	7.8	14.2	11.3	8.04
T02P05	Cseg2	111	18.21	8.3	9.91	1.19	0.55	1.934	8.6	16.6	13.3	8.25
T02P05	Cseg3	141	18.96	8.15	10.81	1.33	0.54	2.35	7.9	18.7	14.9	8.15
T02P06	Ase1	8	21.79	9.27	12.52	1.35	0.62	2.39	7.0	16.7	13.4	8.2
T02P06	Ase2	21	22.12	10.71	11.41	1.07	0.71	2.22	7.6	16.8	13.4	8.05

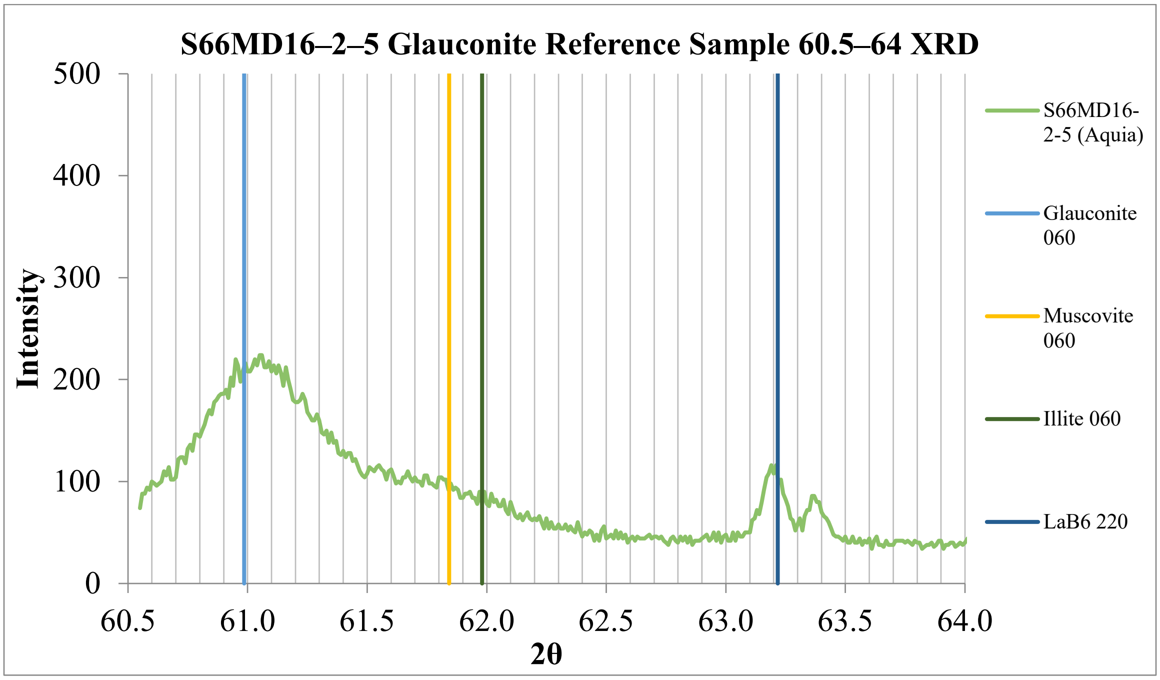
T02P06	Cseg1	40	22.74	13.45	9.29	0.69	0.90	1.616	9.1	14.7	11.7	9.06
T02P06	Cseg2	49	28.15	20.42	7.73	0.38	1.36	1.396	10.7	14.9	12.0	8.65
T02P06	Cg	71	24.83	19.88	4.95	0.25	1.33	1.029	16.2	16.6	13.3	8.26
T03P01	Ase	10	25.35	20.4	4.95	0.24	1.36	0.871	16.2	14.1	11.3	7.33
T03P01	Cseg	25	26.75	22.12	4.63	0.21	1.47	0.668	17.2	11.5	9.2	8.3
T03P01	2BCsegb	42	28.26	22.84	5.42	0.24	1.52	0.301	14.8	4.5	2.9	6.5
T03P01	2BCseb	59	25.48	19.66	5.82	0.30	1.31	0.058	13.9	0.8	0.5	5.96
T03P02	Ase1	15	26.15	21.04	5.11	0.24	1.40	0.897	15.7	14.1	11.2	7.85
T03P02	Ase2	39	27.86	22.94	4.92	0.21	1.53	0.972	16.2	15.8	12.6	7.86
T03P02	Cseg1	74	30.59	25.17	5.42	0.22	1.68	1.102	14.8	16.4	13.1	6.55
T03P02	2Cseg2	84	31.43	26.41	5.02	0.19	1.76	0.918	15.9	14.6	11.7	6.37
T03P02	2Cseg3	117	27.81	20.86	6.95	0.33	1.39	1.063	11.8	12.5	10.0	6.95
T03P02	2Cseg4	137	30.37	23.85	6.52	0.27	1.59	0.967	12.5	12.1	9.7	6.6
T03P03	A	8	26.09	21.15	4.94	0.23	1.41	1.127	16.2	18.2	14.6	7.5
T03P03	Acg	27	28.18	24.14	4.04	0.17	1.61	0.716	19.6	14.0	11.2	8.41
T03P03	2BCb1	48	27.26	22.4	4.86	0.22	1.49	0.921	16.4	15.1	12.1	8.62
T03P03	2BCb2	61	28.5	22.62	5.88	0.26	1.51	1.18	13.8	16.2	13.0	8.12
T03P03	2Cg	81	27.13	22.25	4.88	0.22	1.48	0.927	16.4	15.2	12.1	8.3
T03P03	2C	110	5.87	4.71	1.16	0.25	0.31	1.552	11.8	18.3	14.6	7.66
T03P04	Aseg	10	26.21	21.1	5.11	0.24	1.41	0.946	15.7	14.8	11.9	7
T03P04	Ase	24	26.78	21.54	5.24	0.24	1.44	0.863	15.3	13.2	10.6	8.1
T03P04	2Btgb1	38	29.68	23.64	6.04	0.26	1.58	0.681	13.4	9.1	7.3	7.63
T03P04	2Btgb2	65	24.89	20.93	3.96	0.19	1.40	0.622	19.9	12.4	9.9	7.1
T03P04	2Btb1	79	27.4	21.83	5.57	0.26	1.46	0.677	14.5	9.8	7.8	6.53
T03P04	2BCtb	119	26.12	21.11	5.01	0.24	1.41	1.179	16.0	18.8	15.1	6.1
T03P04	2BCtgb	147	26.86	21.32	5.54	0.26	1.42	1.346	14.5	19.6	15.7	6.1
T03P06	Ase1	6	26.49	19.58	6.91	0.35	1.31	1.287	11.9	15.3	12.2	7.29
T03P06	Ase2	19	27.89	21.08	6.81	0.32	1.41	1.184	12.0	14.2	11.4	7.49

T03P06	ACg	44	27.76	22.99	4.77	0.21	1.53	1.155	16.7	19.3	15.5	8.35
T03P06	2Bgb1	65	29.14	22.44	6.7	0.30	1.50	1.545	12.2	18.8	15.1	8.71
T03P06	2Bgb2	104	26.17	21	5.17	0.25	1.40	1.494	15.5	23.2	18.5	8.33
T04P02	ACg	37	28.39	22.99	5.4	0.23	1.53	1.035	14.9	15.4	12.3	7.46
T04P02	Cg1	97	25.57	20.71	4.86	0.23	1.38	1.607	16.4	26.4	21.1	6.72
T04P02	Cg2	141	25.55	20.5	5.05	0.25	1.37	1.397	15.9	22.1	17.7	8.2
T04P02	Cg3	171	29.22	22.74	6.48	0.28	1.52	2.18	12.6	27.4	21.9	8.56
T04P03	Ase1	30	21.21	6.74	14.47	2.15	0.45	2.75	6.2	17.0	13.6	8.07
T04P03	Ase2	50	20.04	6.55	13.49	2.06	0.44	2.92	6.6	19.2	15.3	8.08
T04P03	Ase3	70	20.12	7.02	13.1	1.87	0.47	3.17	6.7	21.3	17.1	7.78
T04P03	Cseg1	103	21.06	8.32	12.74	1.53	0.55	2.34	6.9	16.1	12.9	7.66
T04P03	Cseg2	127	20.46	8.26	12.2	1.48	0.55	2.71	7.1	19.4	15.5	7.54
T04P03	Cseg3	155	21.05	8.83	12.22	1.38	0.59	2.61	7.1	18.6	14.9	7.55
T04P03	Cseg4	173	22.47	9.71	12.76	1.31	0.65	2.38	6.9	16.4	13.1	7.66
T04P04	Aseg	13	24.95	20.42	4.53	0.22	1.36	0.919	17.6	16.1	12.9	7.37
T04P04	Cseg1	51	25.13	20.91	4.22	0.20	1.39	0.938	18.8	17.6	14.1	8.3
T04P04	Cseg2	66	25.17	20.39	4.78	0.23	1.36	0.84	16.7	14.0	11.2	7.9
T04P05	Ase	14	26.57	21.03	5.54	0.26	1.40	0.878	14.5	12.8	10.2	7.4
T04P05	Cseg	48	24.07	19.53	4.54	0.23	1.30	0.974	17.5	17.1	13.7	7.68
T04P05	ACg	96	26.07	21.01	5.06	0.24	1.40	1.353	15.8	21.4	17.1	7.61
T04P05	Cg	140	24.68	20.14	4.54	0.23	1.34	1.558	17.5	27.3	21.8	7.08
T05P06	Aseg	7	27.63	22.12	5.51	0.25	1.47	1.089	14.6	15.9	12.7	7.96
T05P06	Cseg	16	28.42	23.02	5.4	0.23	1.53	1.165	14.9	17.3	13.9	8.02
T05P06	ACg	30	31.07	25.25	5.82	0.23	1.68	1.164	13.9	16.2	12.9	7.89
T05P06	Cg1	52	25.58	21.18	4.4	0.21	1.41	1.336	18.0	24.1	19.3	7.82
T05P06	Cg2	63	27.68	22.46	5.22	0.23	1.50	1.48	15.4	22.7	18.2	8.25
T05P07	Ase	4	24.78	17.72	7.06	0.40	1.18	1.055	11.6	12.3	9.8	7.32
T05P07	Cg1	32	24.07	20.08	3.99	0.20	1.34	0.915	19.8	18.1	14.5	6.95

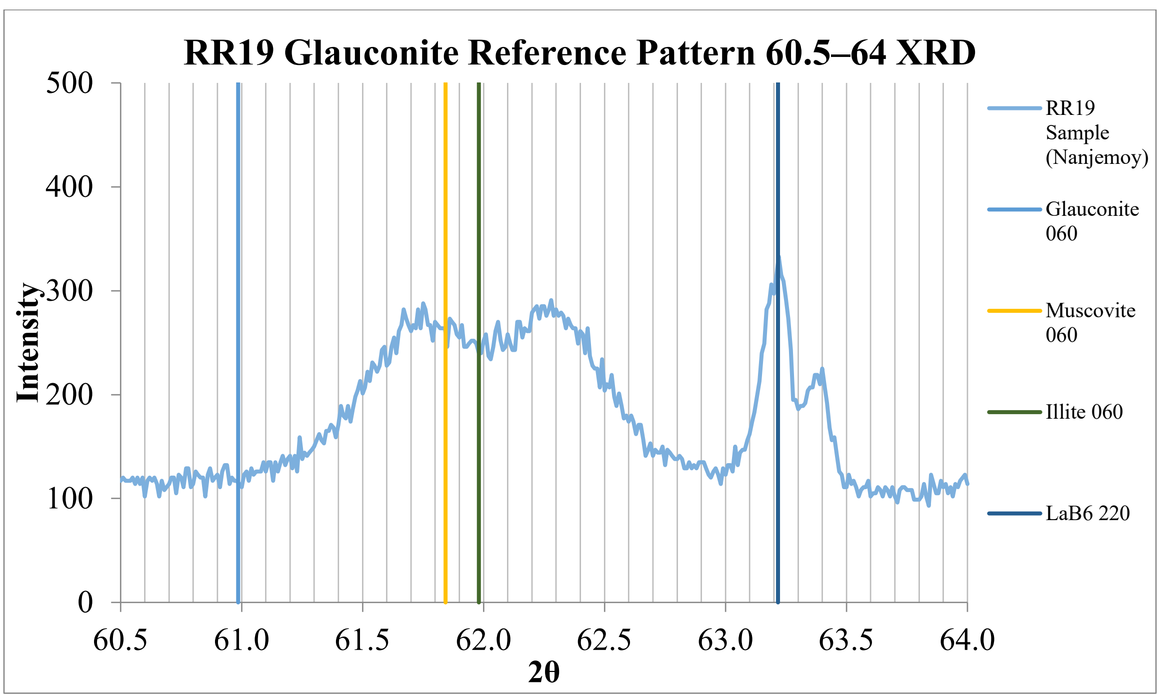
T05P07	Cg2	68	26.53	21.86	4.67	0.21	1.46	1.244	17.1	21.2	17.0	6.88
T05P07	Cg3	105	25.08	20.71	4.37	0.21	1.38	1.59	18.2	28.9	23.1	7.41
T05P07	Agb	116	25.15	17.59	7.56	0.43	1.17	2.21	10.9	24.1	19.3	7.69
T05P07	C'g1	135	23.64	17.31	6.33	0.37	1.15	1.741	12.8	22.4	17.9	7.69
T05P07	C'g2	161	24.54	17.66	6.88	0.39	1.18	2.34	11.9	27.8	22.3	7.09
T05P07	C'g3	186	23.54	19.3	4.24	0.22	1.29	1.217	18.7	22.7	18.2	7.27
T05P07	2BCgb	209	29.89	23.08	6.81	0.30	1.54	1.306	12.0	15.7	12.6	7.8
T05P07	2CBgb	232	23.03	15.83	7.2	0.45	1.06	1.124	11.4	12.8	10.3	7.55
T06P02	Ase	20	20.12	8.36	11.76	1.41	0.56	0.992	7.4	7.3	5.9	8.11
T06P02	Cseg1	38	21.21	9.13	12.08	1.32	0.61	1.552	7.2	11.2	9.0	8.01
T06P02	Cseg2	50	21.61	9.08	12.53	1.38	0.61	1.44	7.0	10.1	8.0	8
T06P02	Aseb1	84	25.02	12.83	12.19	0.95	0.86	1.444	7.2	10.3	8.3	8.09
T06P02	Aseb2	123	21.77	12.01	9.76	0.81	0.80	1.338	8.7	11.6	9.3	8.09
T06P02	C'seg	176	20.51	10.89	9.62	0.88	0.73	1.227	8.8	10.8	8.6	7.65
T06P02	2Cg1	226	18.27	6.21	12.06	1.94	0.41	1.515	7.2	10.9	8.7	7.6
T06P02	2Cg2	276	19.87	8.81	11.06	1.26	0.59	1.012	7.8	7.9	6.3	7.51
T06P02	2Cg3	317	18.87	7.84	11.03	1.41	0.52	0.996	7.8	7.8	6.2	7.26

Appendix I. X-Ray Diffraction Spectra

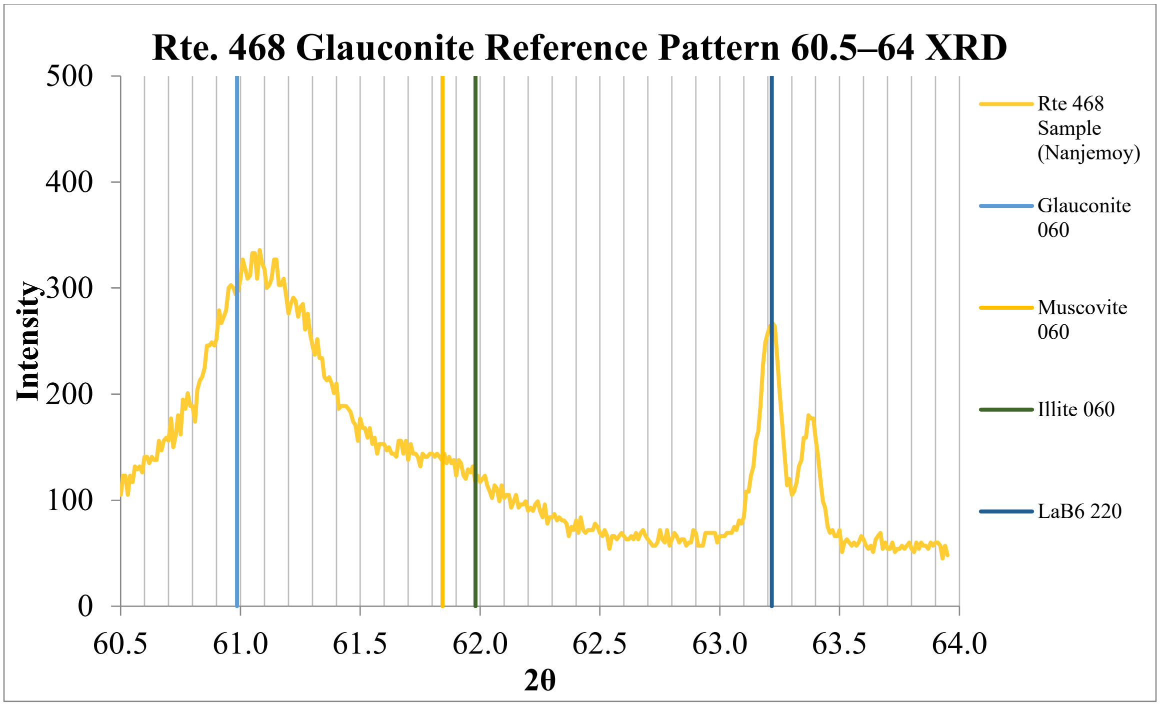
Glauconite Reference Sample XRD Spectra



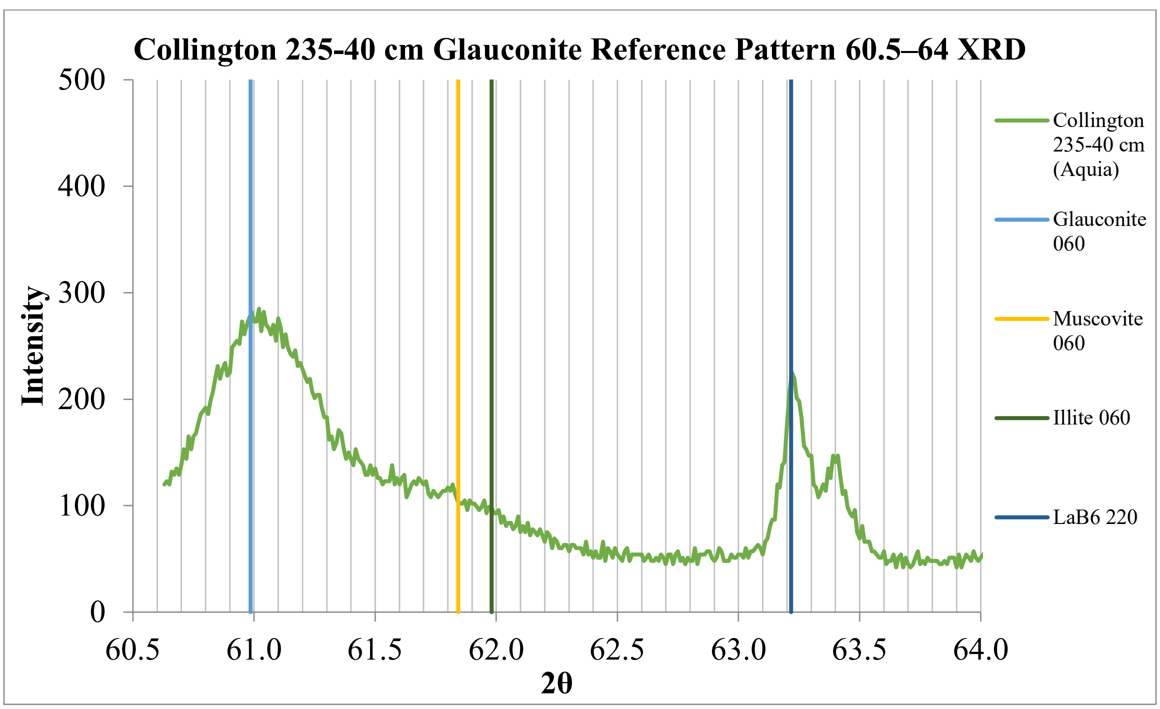
Sample	Glauconite	Muscovite	Illite	Goethite
S66MD16–2–5	XXXX	tr		



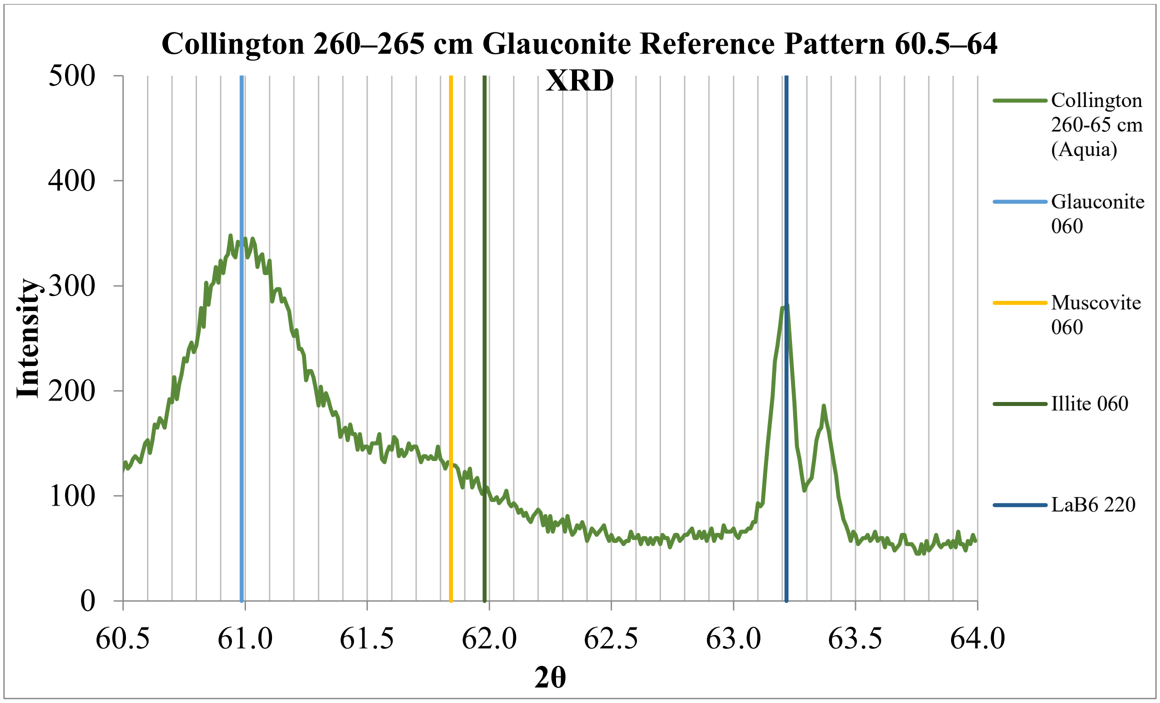
Sample	Glauconite	Muscovite	Illite	Goethite
RR19	tr	XXX		XXX



Sample	Glauconite	Muscovite	Illite	Goethite
Rte. 468	XXXX	tr		

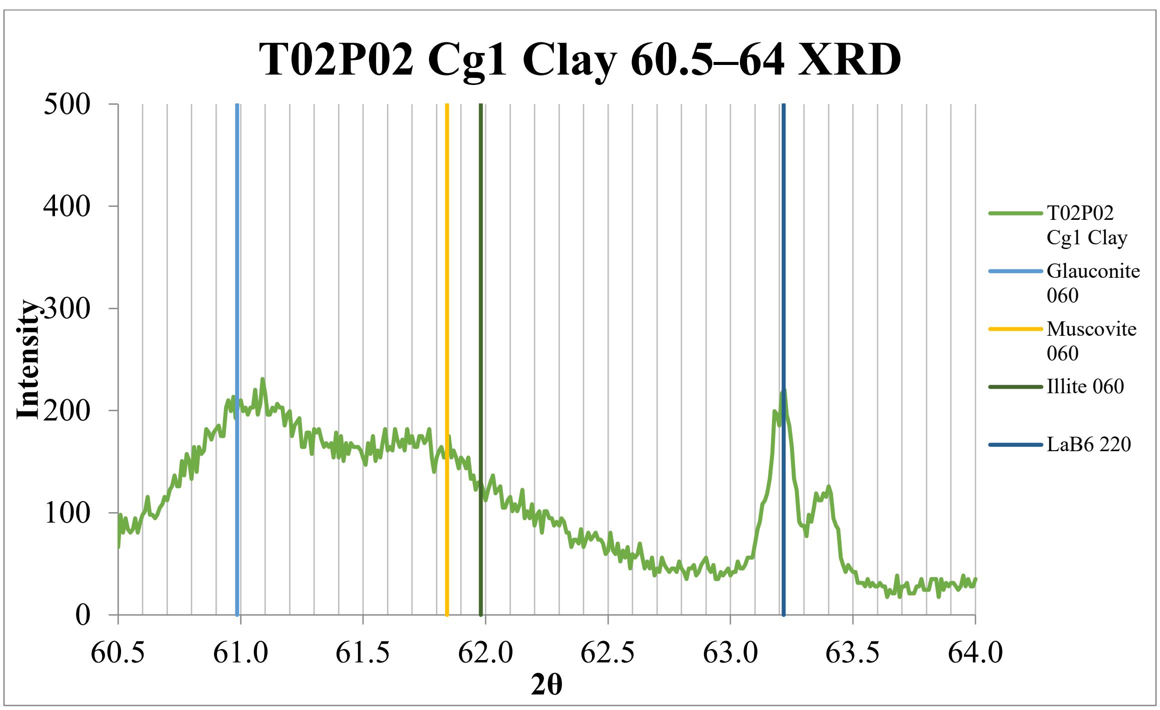


Sample	Glauconite	Muscovite	Illite	Goethite
Collington 235–240 cm	XXXX	tr		

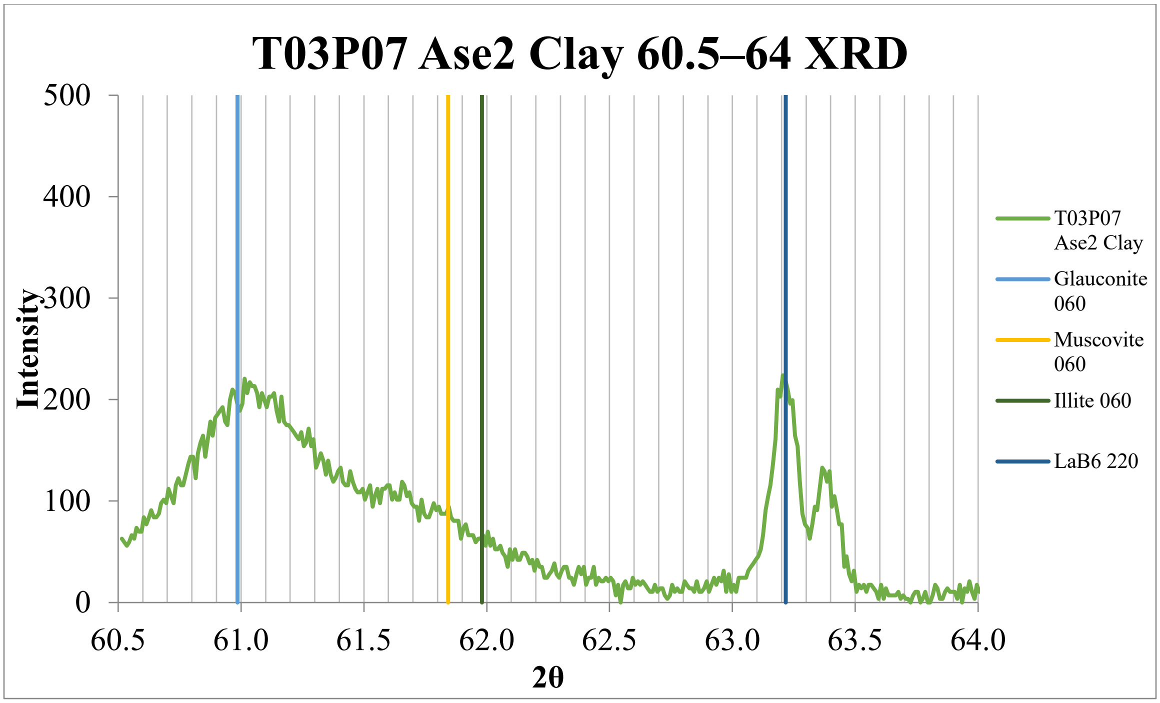


Sample	Glauconite	Muscovite	Illite	Goethite
Collington 260–265 cm	XXXX	tr		

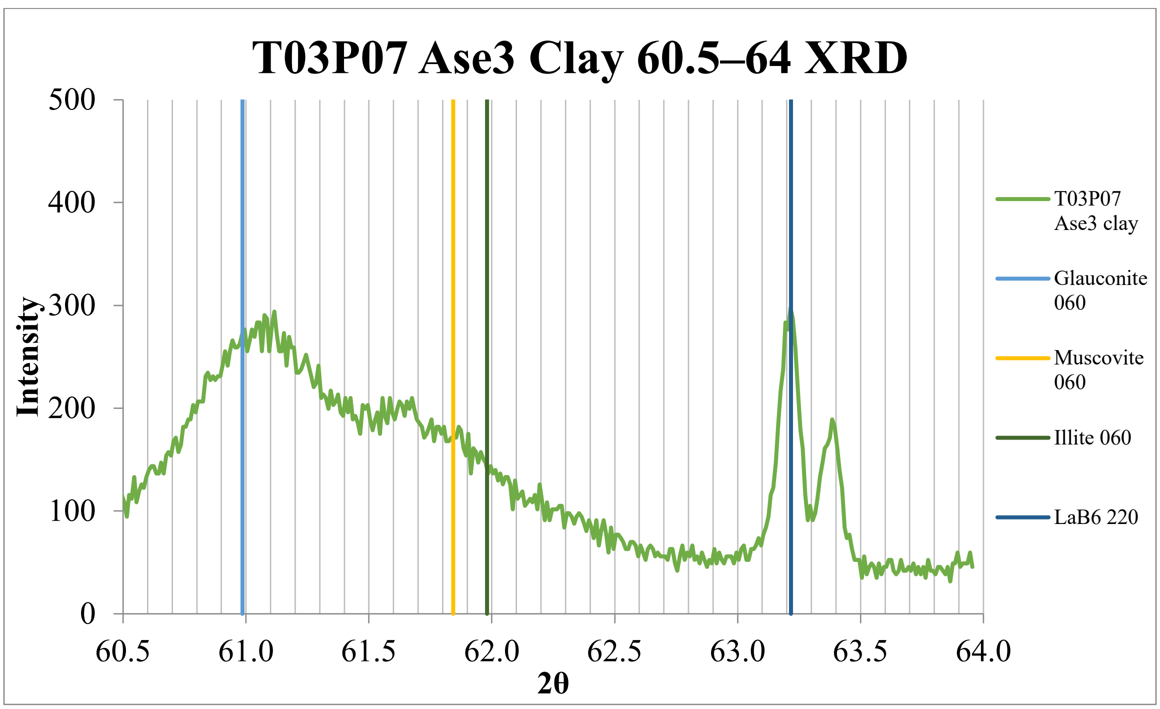
<u>High-Angle Scans on Selected South River Clay Fractions</u>



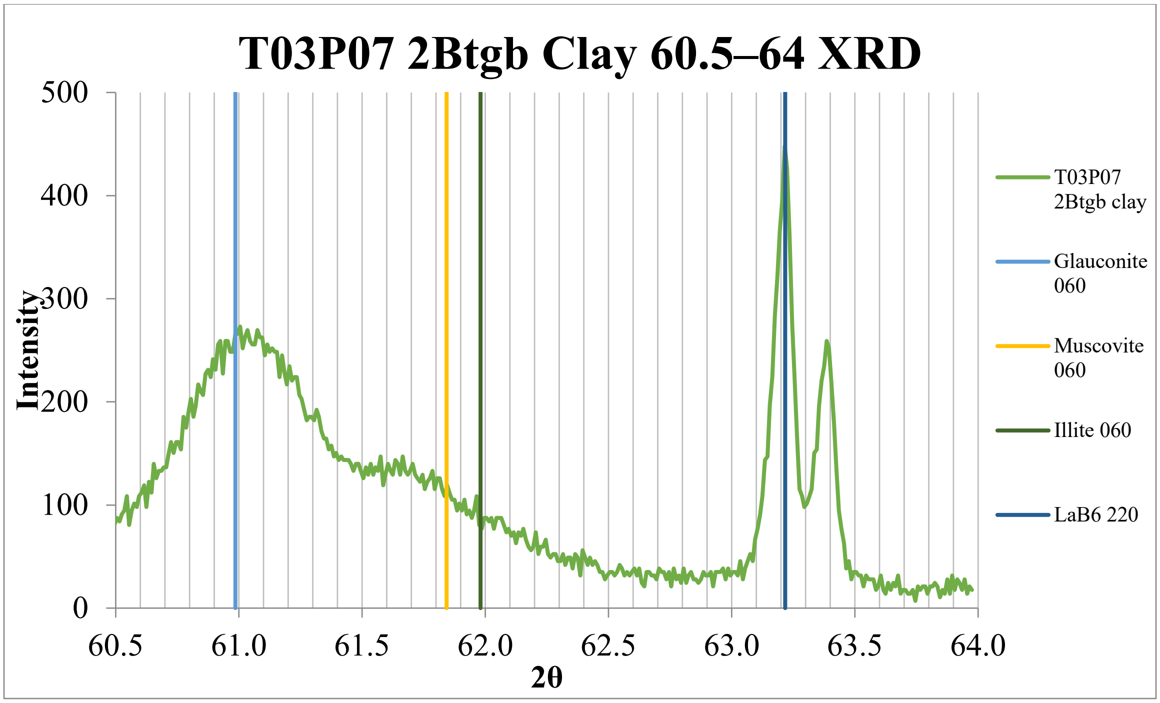
Sample	Glauconite	Muscovite	Illite	Goethite
T02P02 Cg1 clay	XXX	XXX	tr	



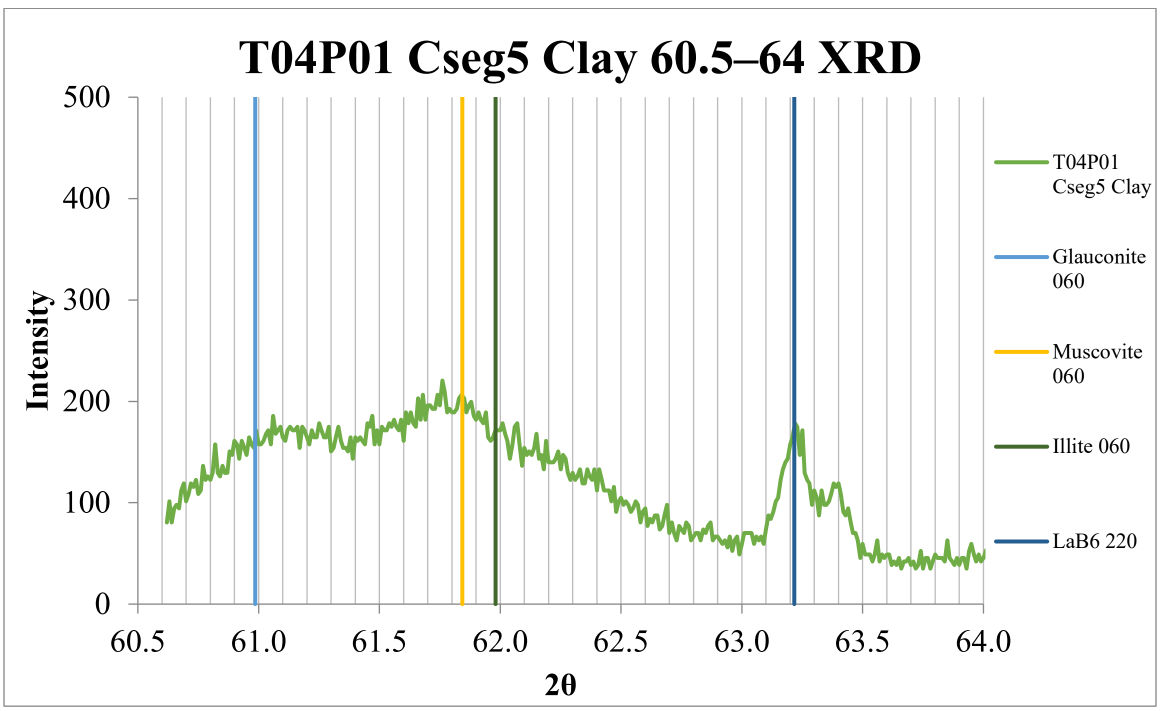
Sample	Glauconite	Muscovite	Illite	Goethite
T03P07 Ase2 clay	XXXX	X	tr	



Sample	Glauconite	Muscovite	Illite	Goethite
T03P07 Ase3 clay	XXXX	X	tr	

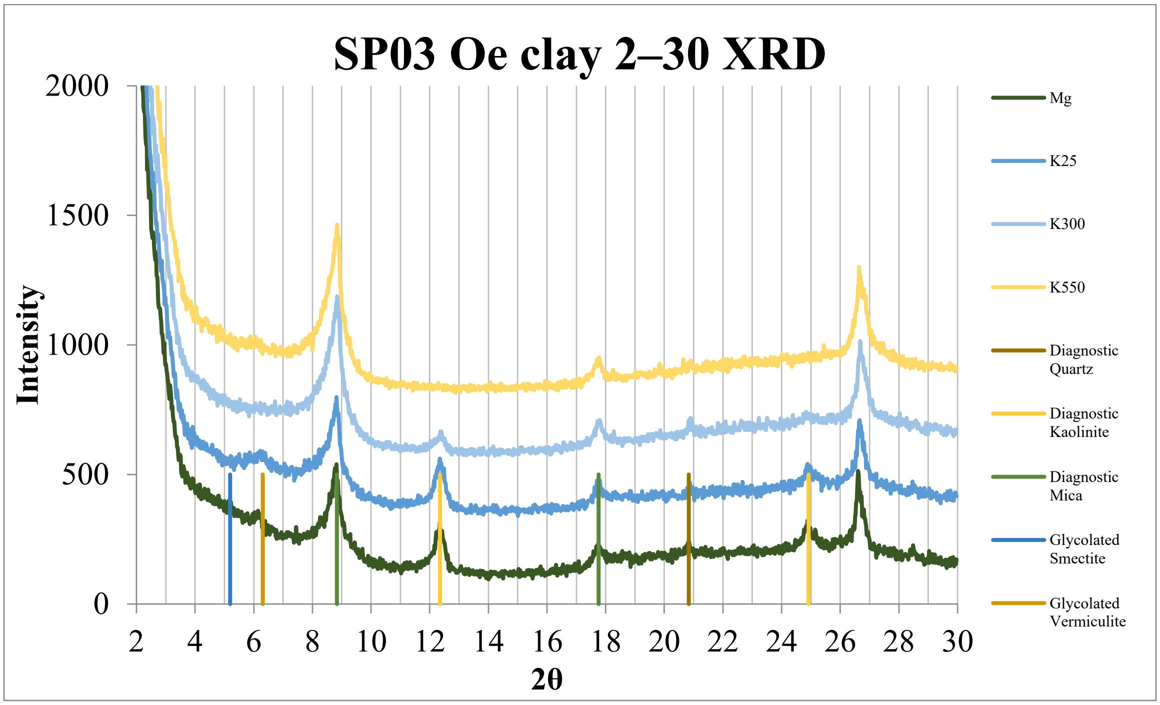


Sample	Glauconite	Muscovite	Illite	Goethite
T03P07 2Btgb clay	XXXX	X	tr	

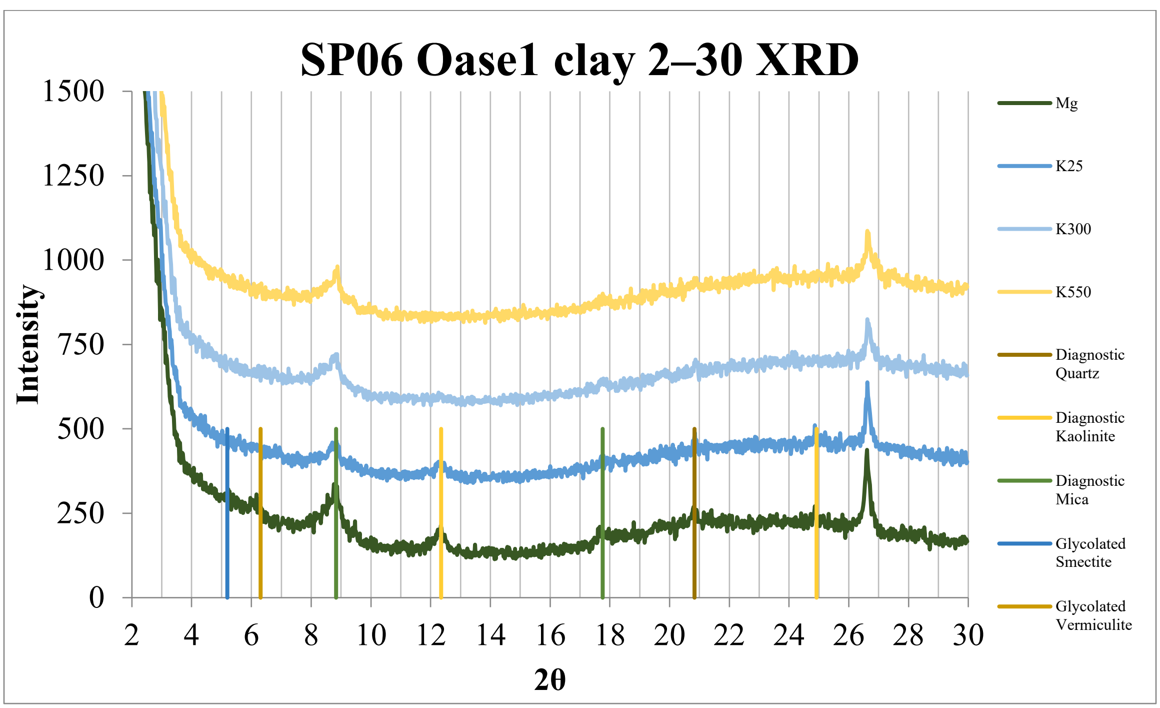


Sample	Glauconite	Muscovite	Illite	Goethite
T04P01 Cseg5 clay	XXX	XXX	tr	

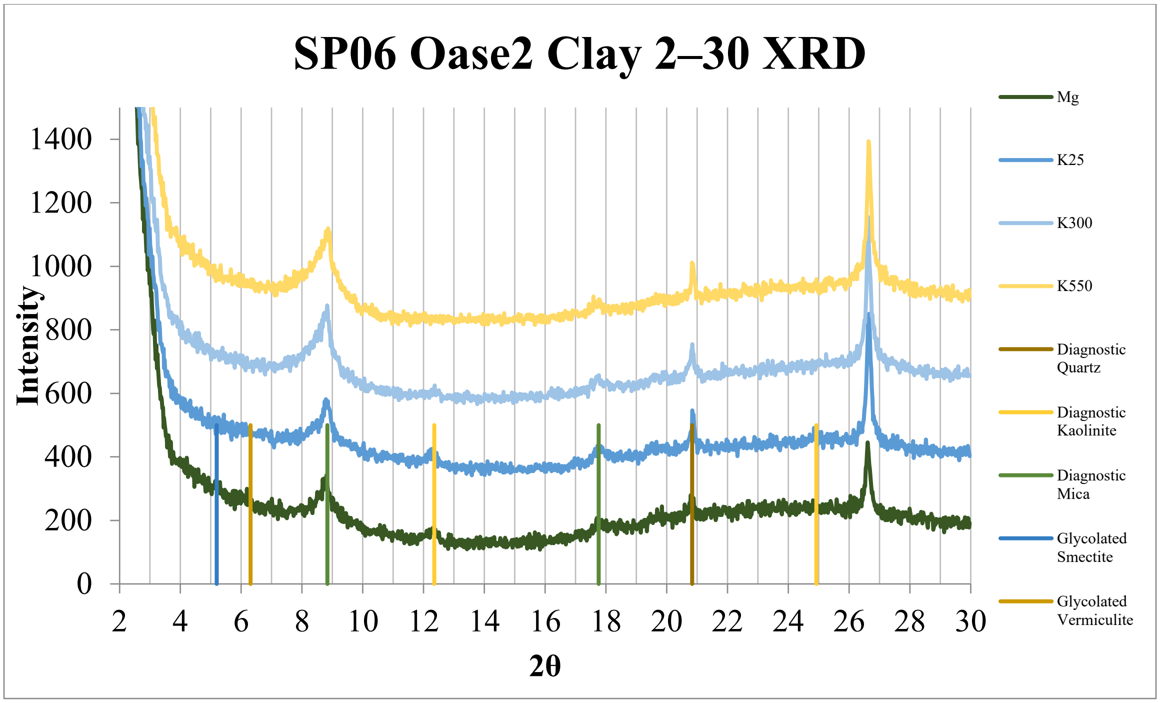
Clay XRD Spectra



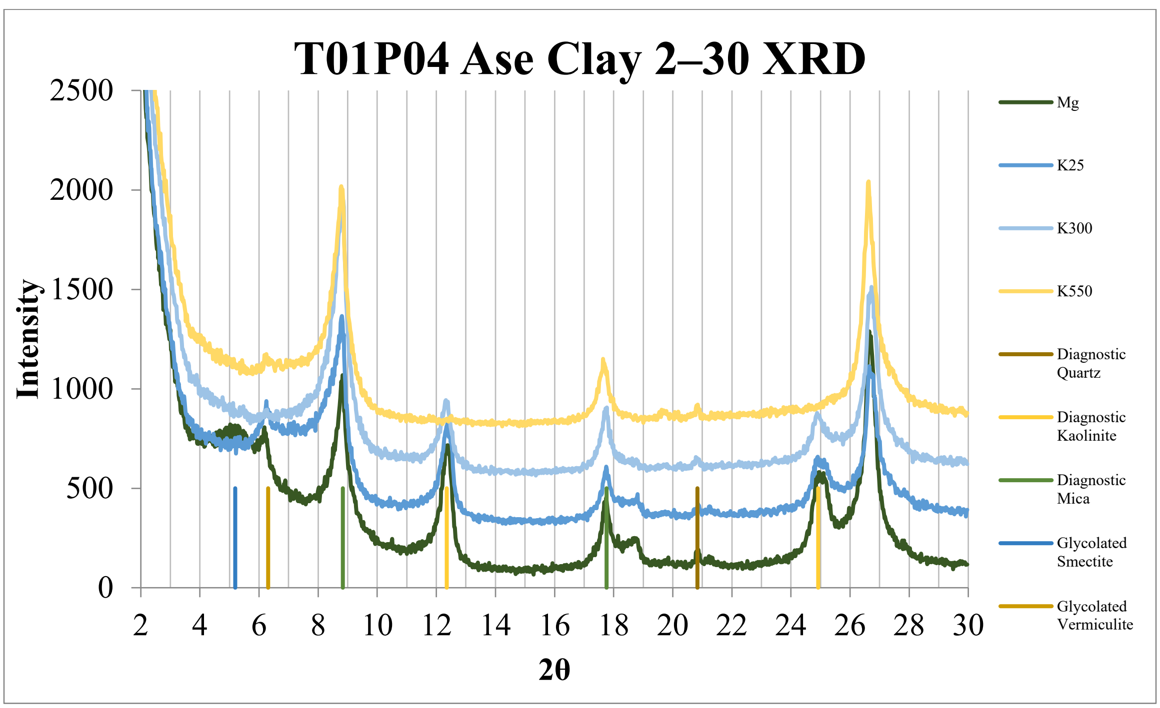
Sample	Quartz	Feldspar	Kaolinite	Mica	Smectite	Vermiculite	Goethite	Ilmenite	Pyrite	Hematite
SP03 Oe clay	X		XX	XXX	X	X				



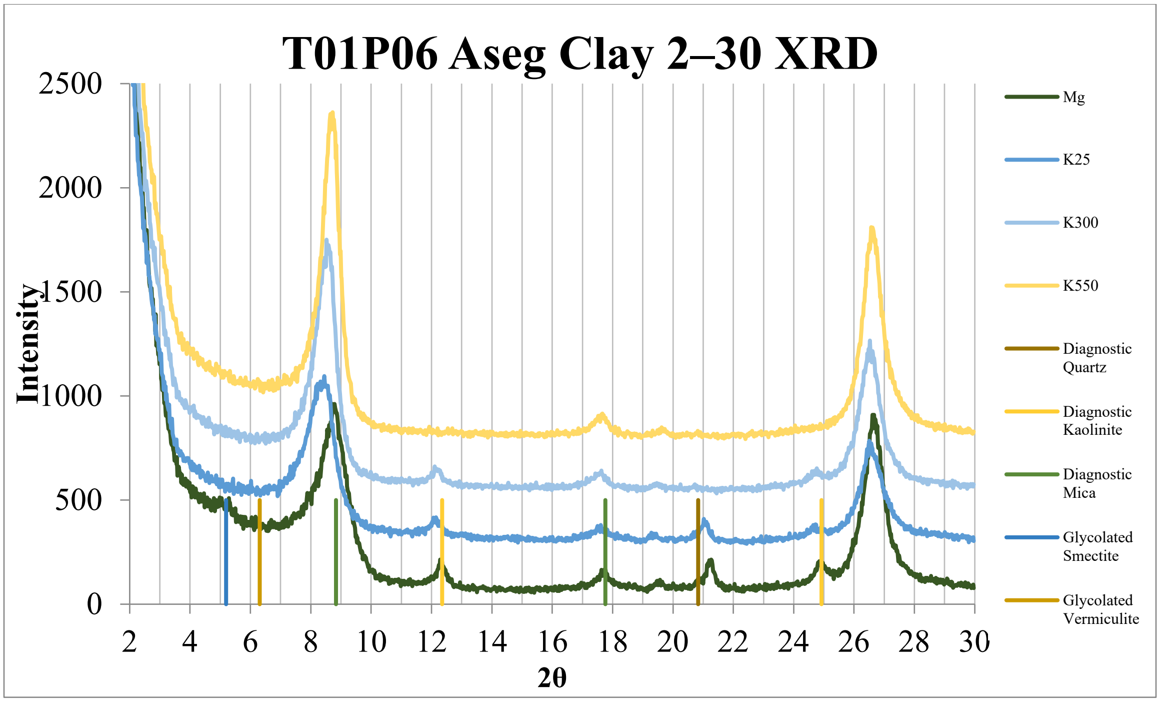
Sample	Quart	Feldspar	Kaolinit	Mica	Smectit	Vermiculite	Goethite	Ilmenit	Pyrit	Hematit
SP06 Oase1	X		XX	XXX	X	XX				



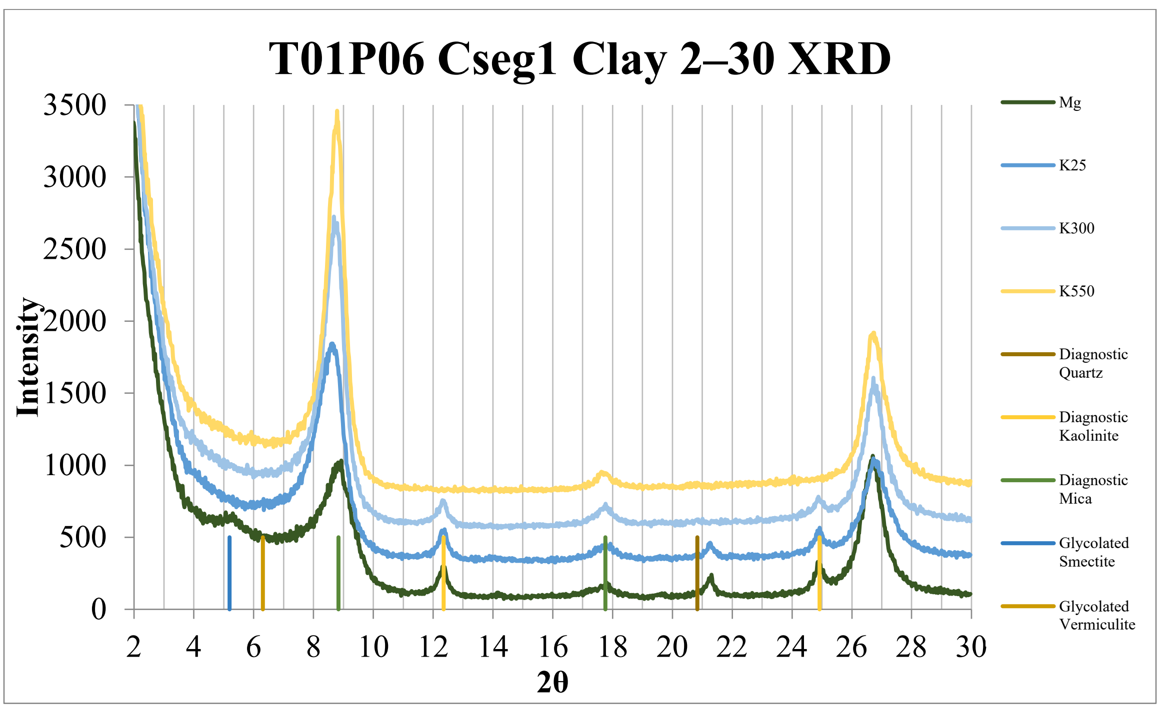
Sample	Quart	Feldspa	Kaolinit	Mica	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
SP06 Oase2 clay	XX		X	XX						



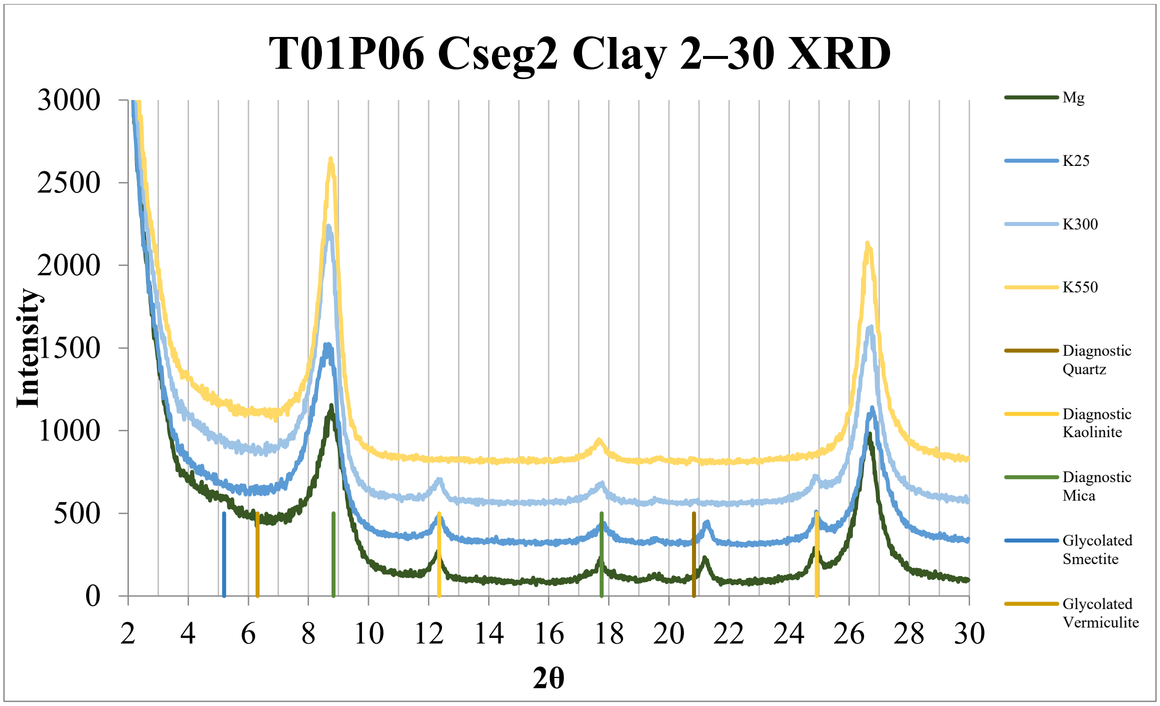
Sample	Quart	Feldspa	Kaolinit	Mica	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T01P04 Ase clay	X		XXX	XX	XX	XX				



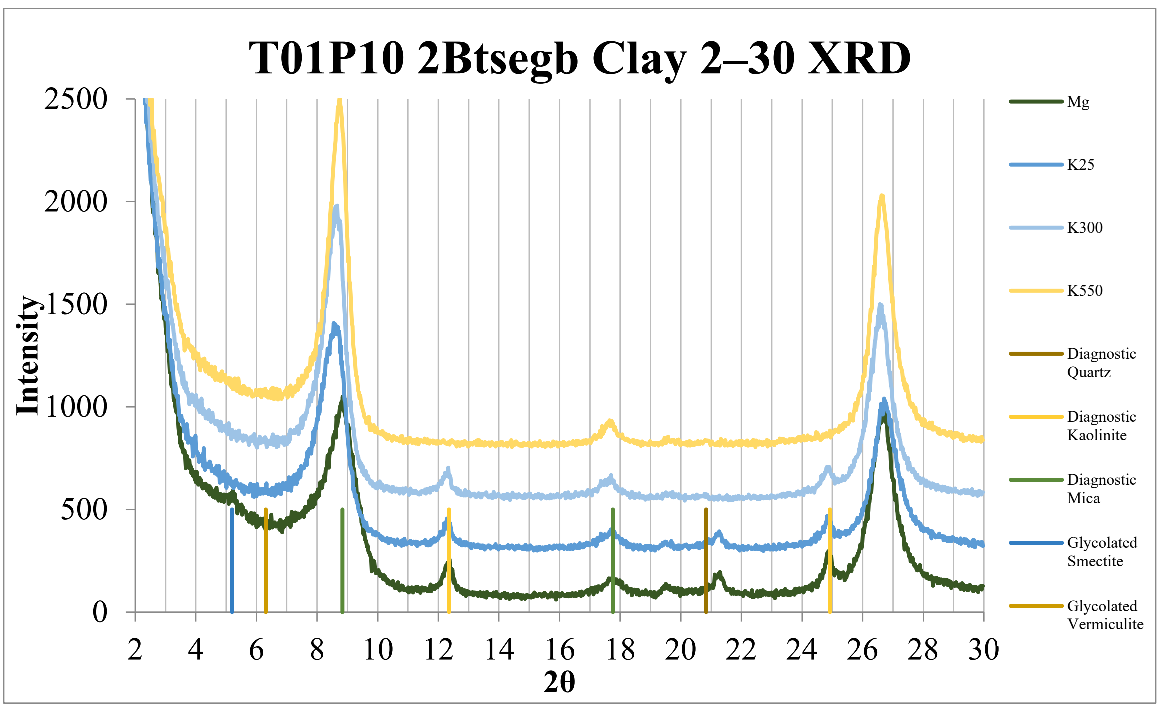
Sample	Quartz	Feldspar	Kaolinit	Mica	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T01P06 Aseg	XX		XX	XXX	X	XX				



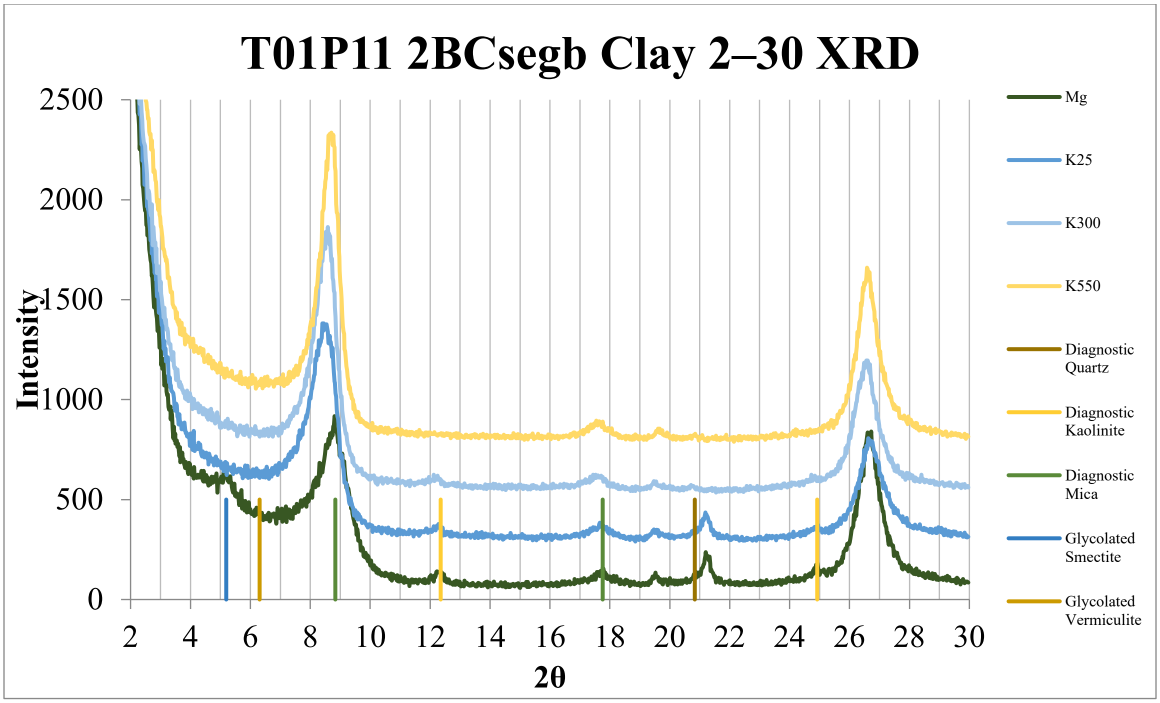
Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T01P06 Cseg1 clay	XX		XX	XX	XX	X				



Sample	Quart	Feldspar	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T01P06 Cseg2	XX		XX	XX	XX	XX				

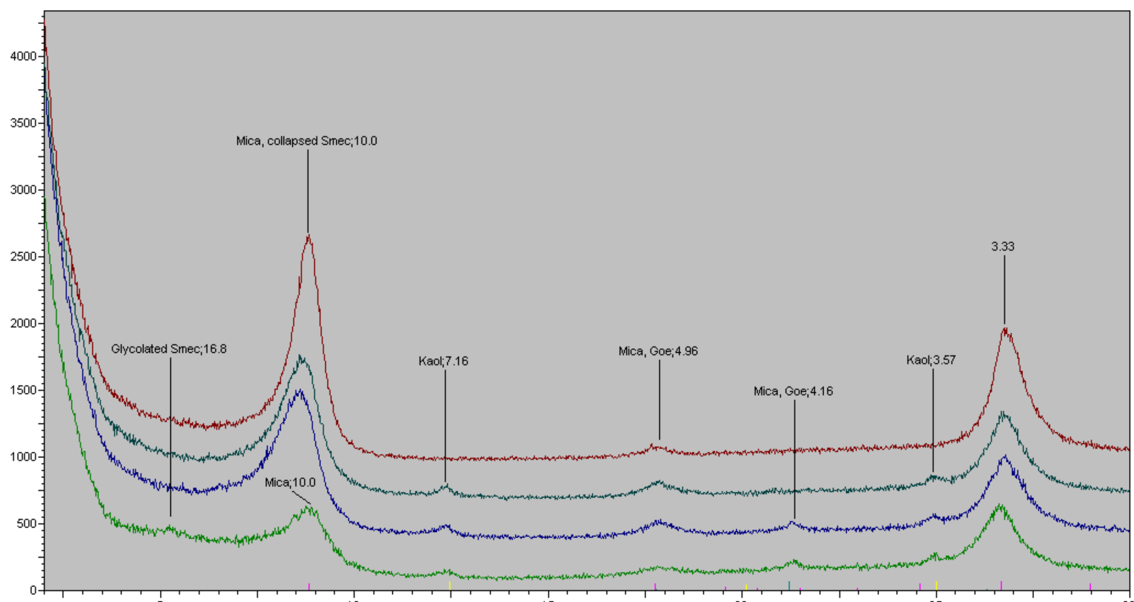


Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T01P10 2Btsegb	XX		XX	XX	XX	XX				

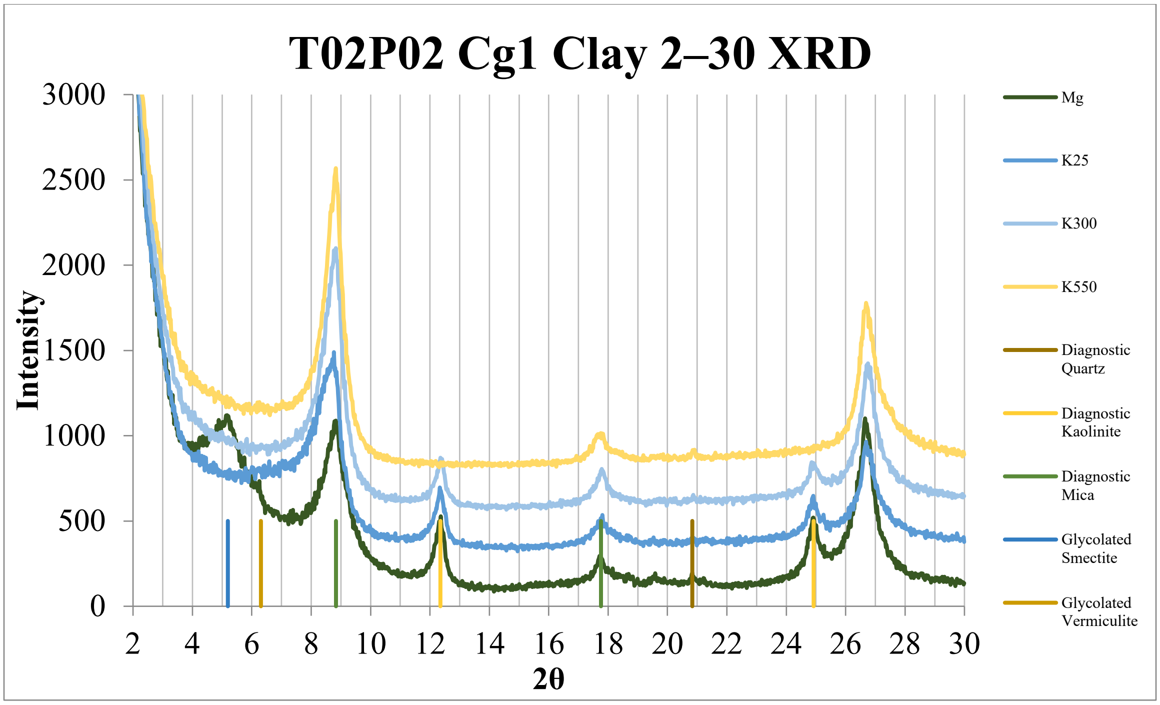


Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T01P11 2BCsegb	XX		X	XX	XX	X				

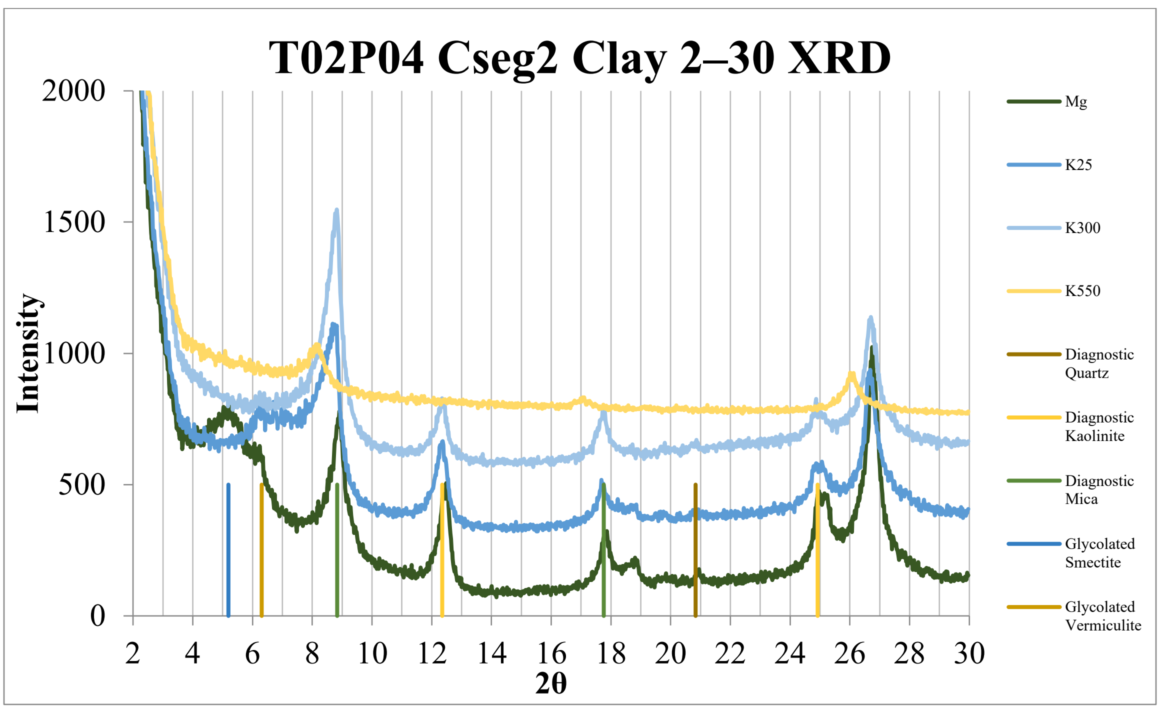
T01P12 2Btsegb3 Clay 2–30 XRD



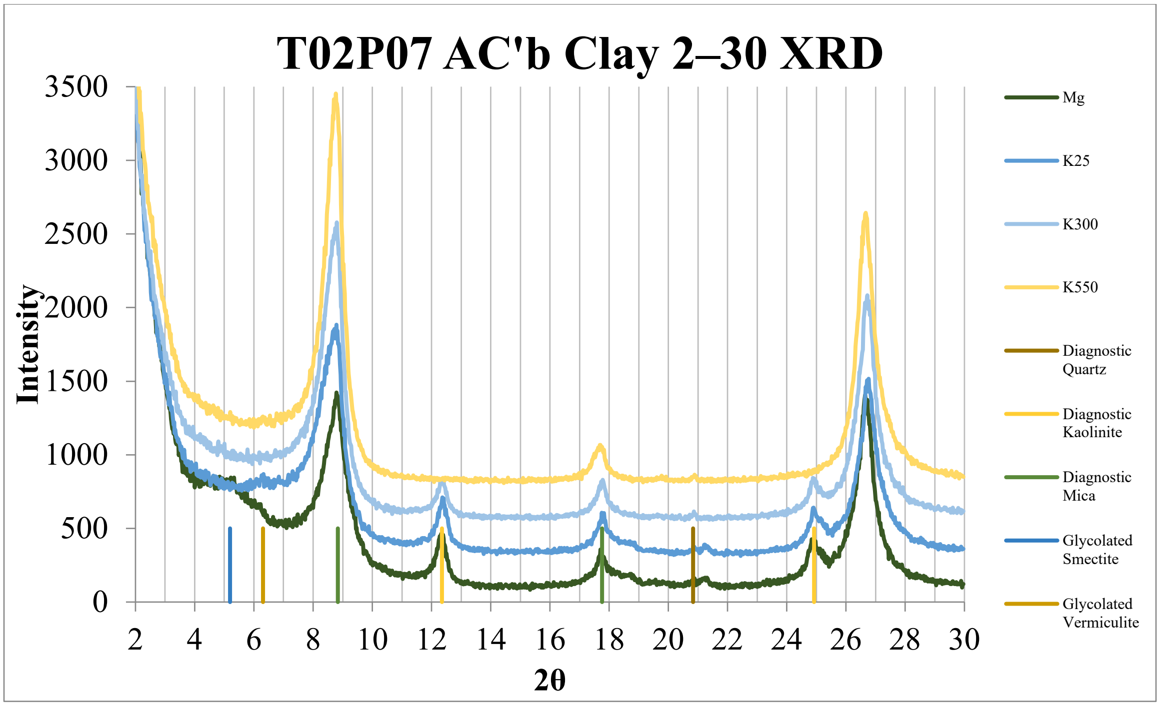
Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T01P12 2Btsegb3			X	XX	XXX		X			



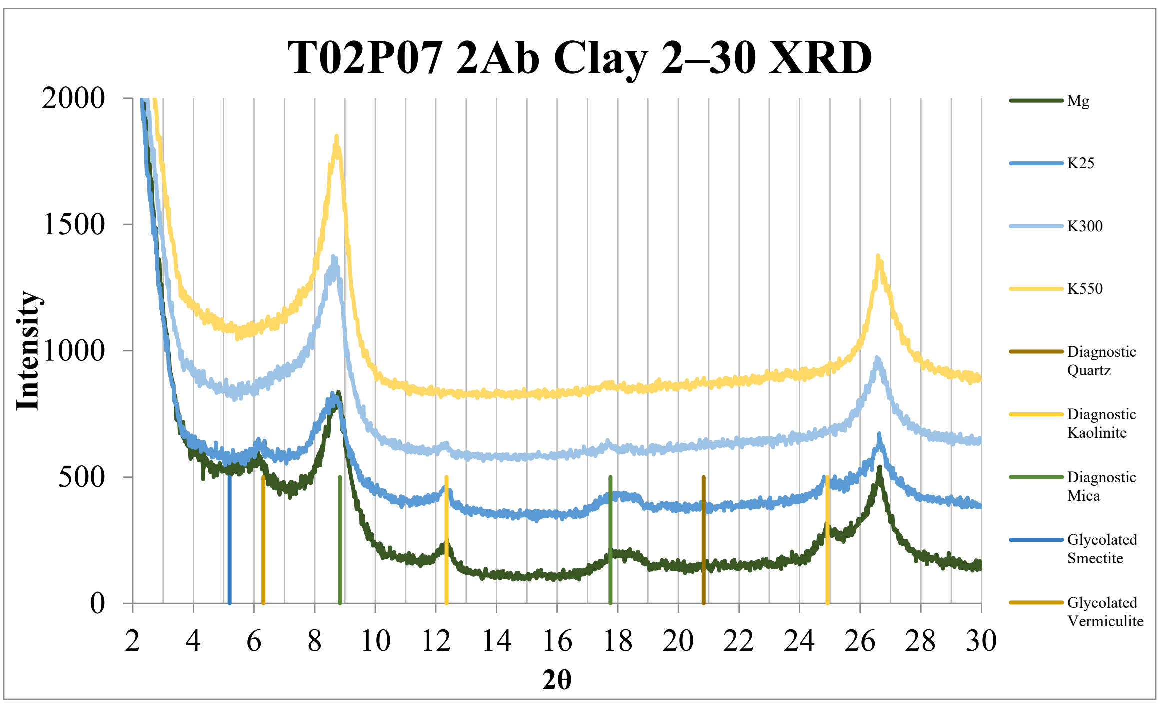
Sample	Quart	Feldspa	Kaolinit	Mica	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T02P02 Cg1 clay			XXX	XX	XXX	XX				



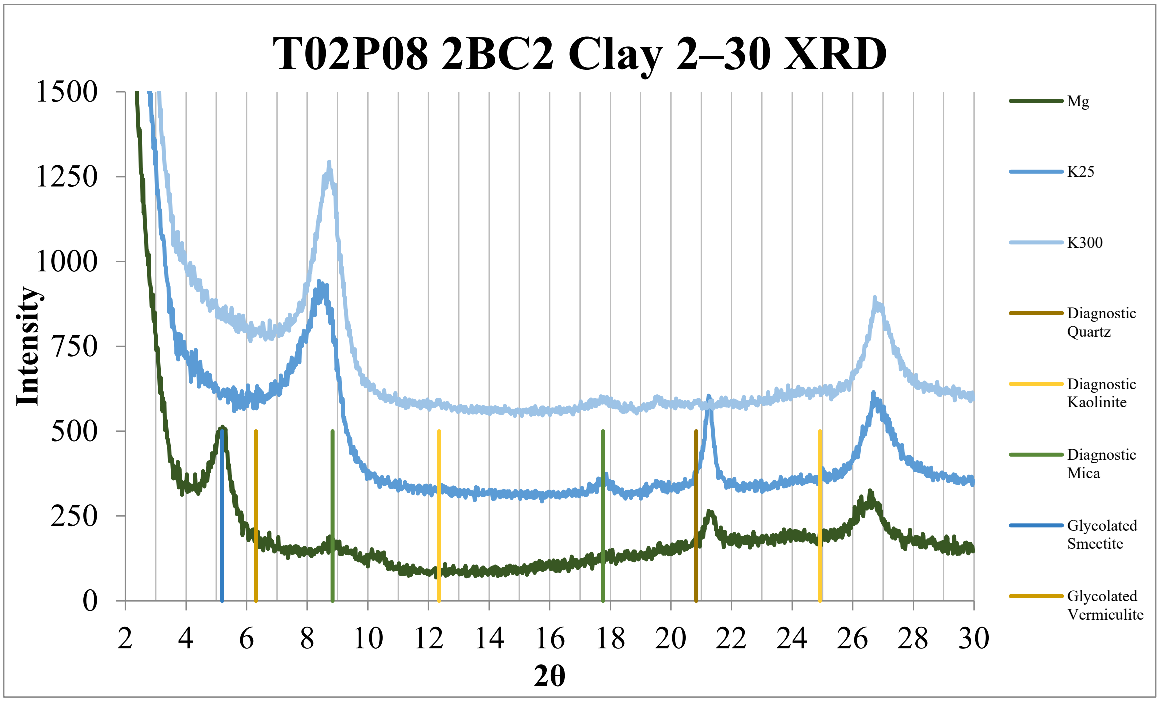
Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T02P04 Cseg2 clay			XXX	XX	XX	XX				



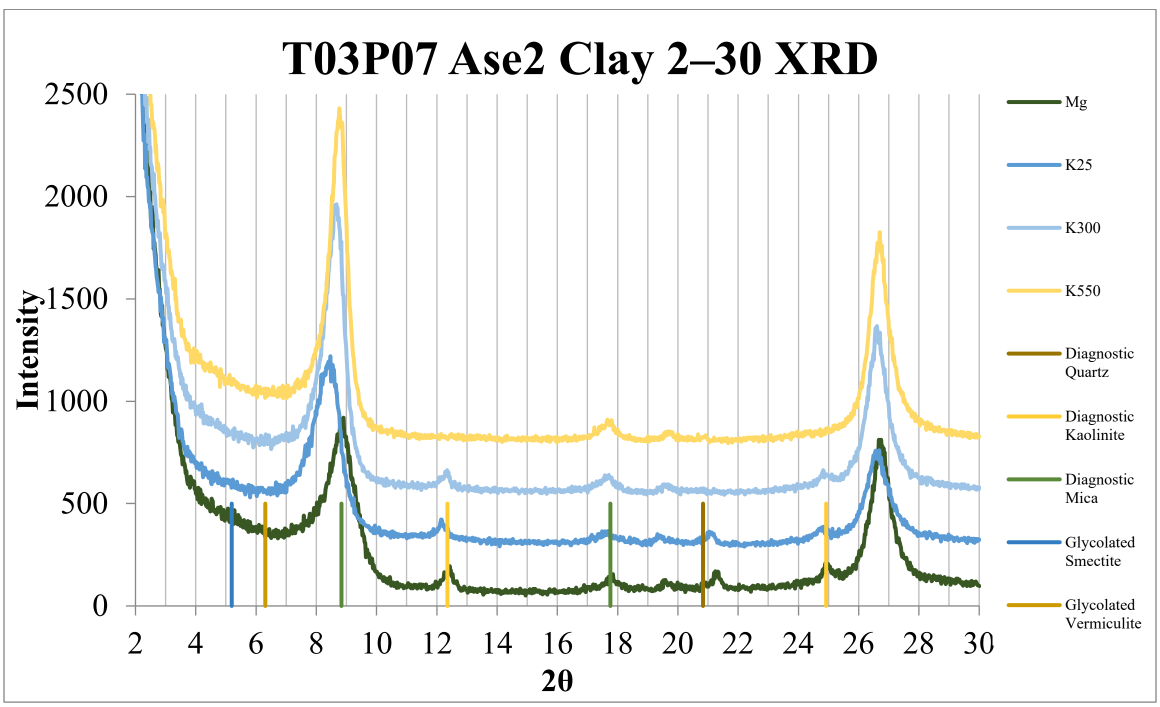
Sample	Quart	Feldspa	Kaolinit	Mica	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T02P07 AC'b clay	X		XX	XX	XX	X				



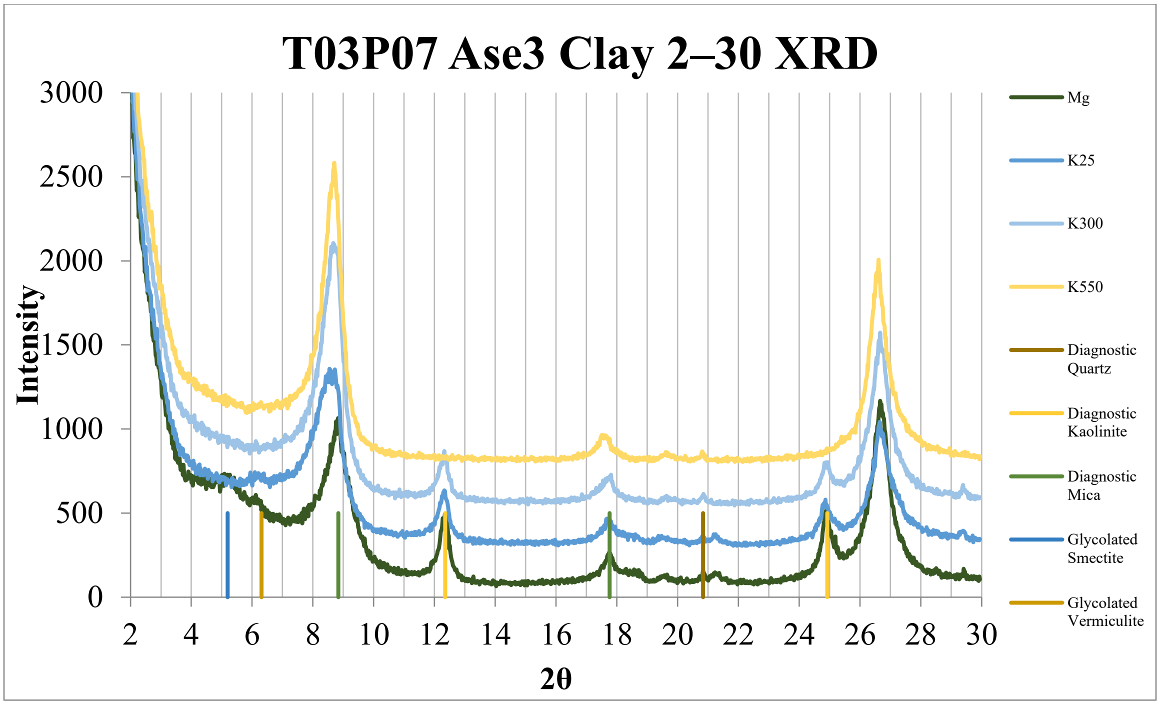
Sample	Quart	Feldspa	Kaolinit	Mica	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T02P07 2Ab clay			X	XX	XX	X				



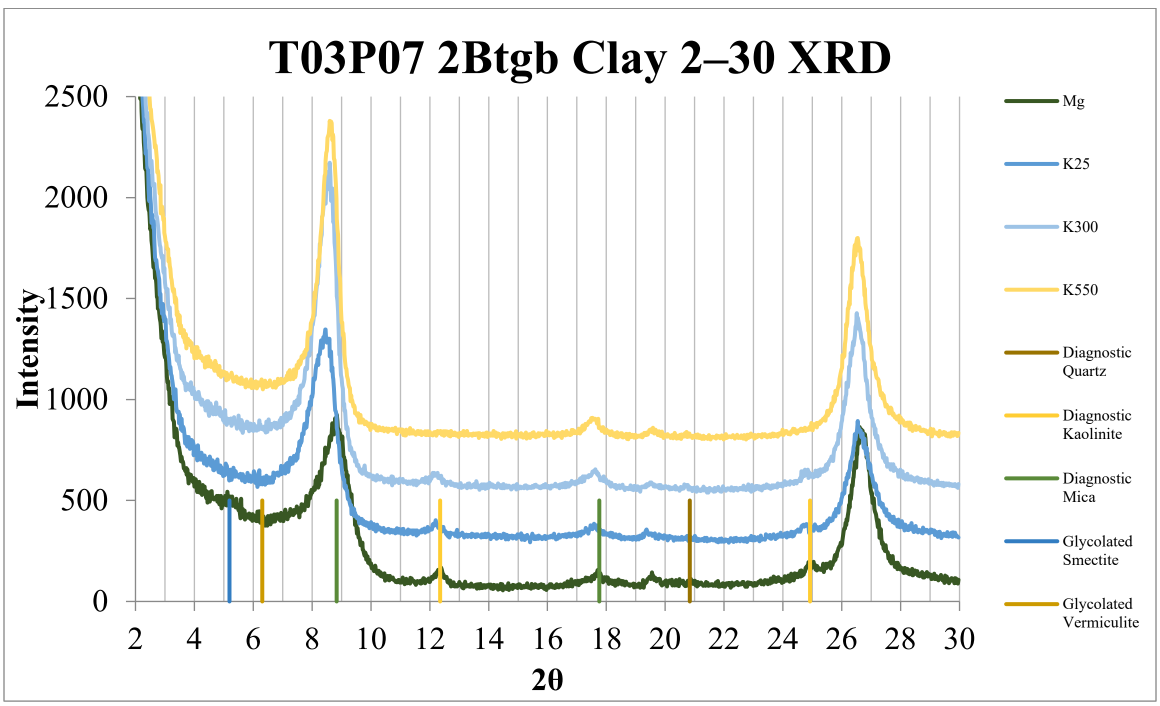
Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T02P08 2BC2 clay					XXXX		XX			



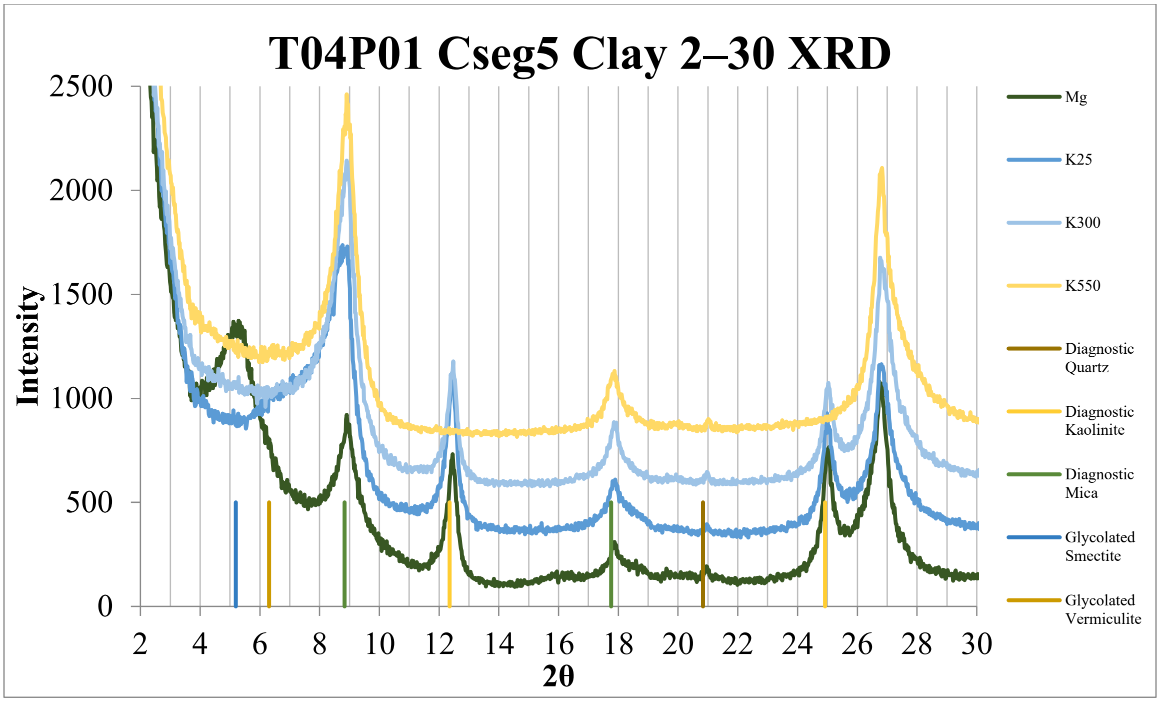
Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T03P07 Ase2 clay	X		XX	XX	XX	XX				



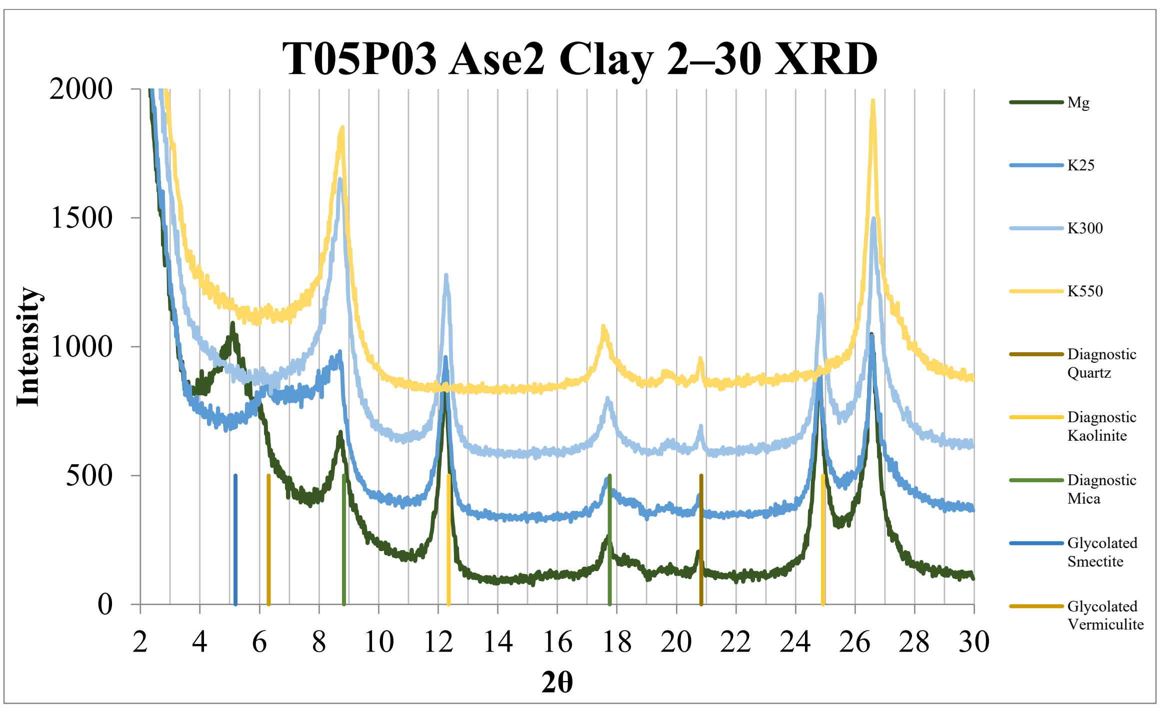
Sample	Quart	Feldspa	Kaolinit	Mica	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T03P07 Ase3 clay	X		XX	XX	XX	X				



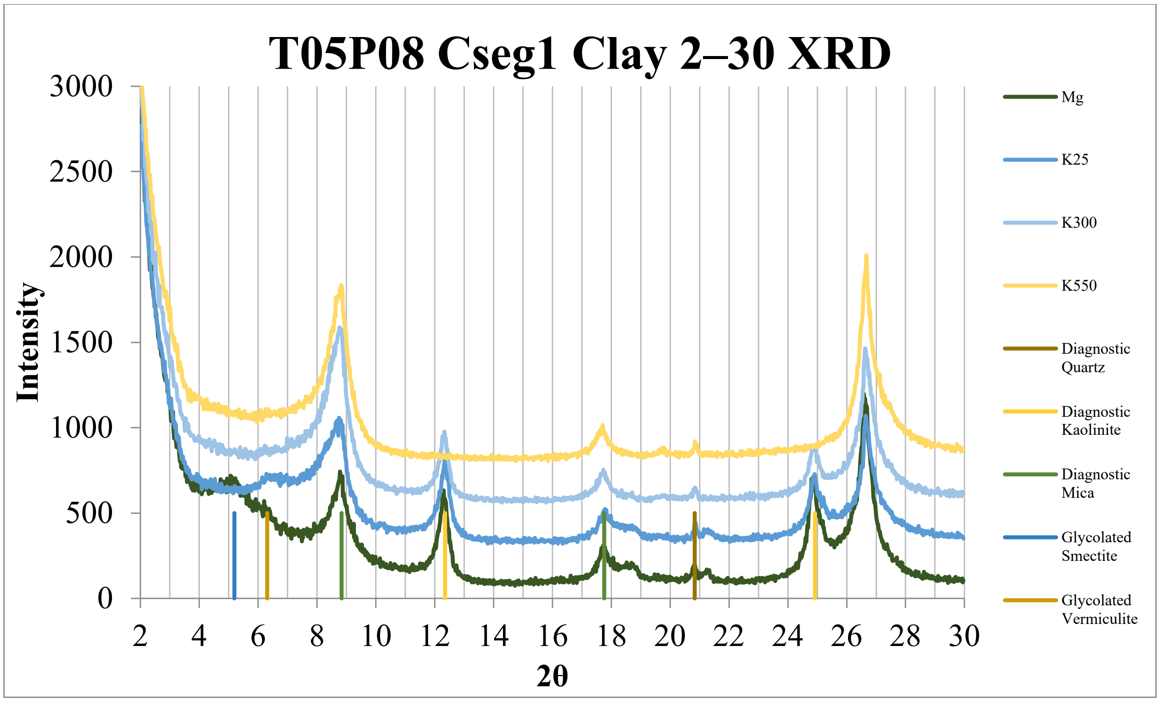
Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T03P07 2Btgb clay			X	XX	XX	XX				



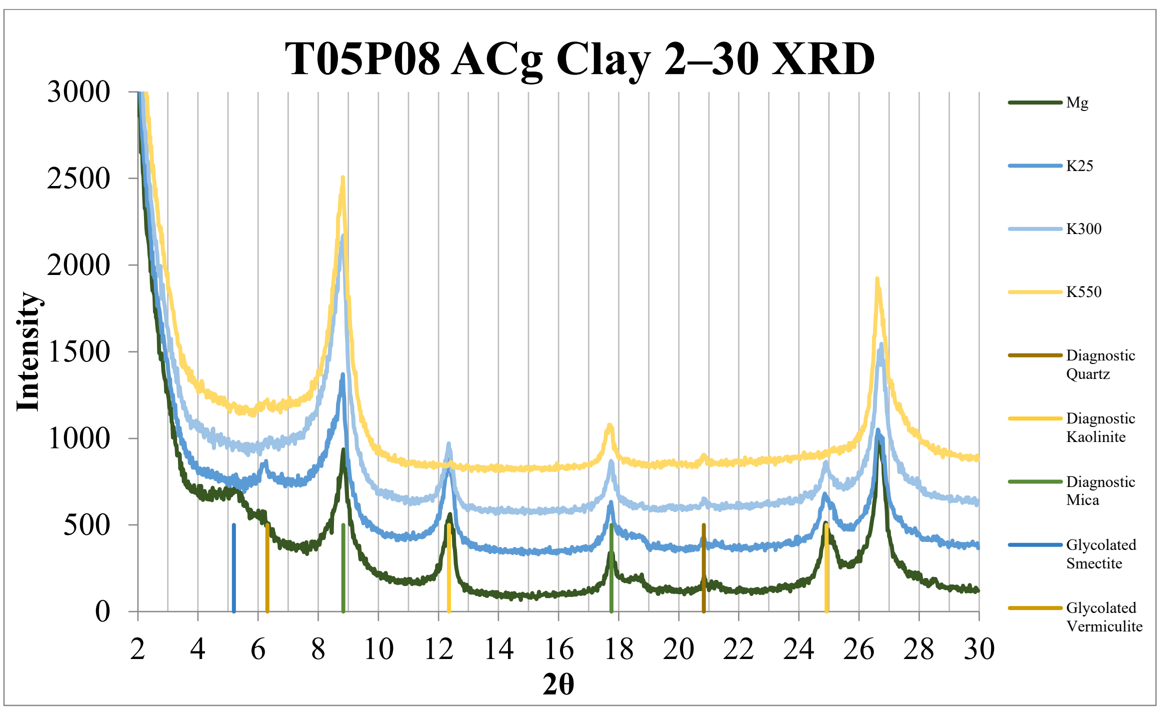
Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T04P01 Cseg5 clay	X		XXX	XX	XXX	X				



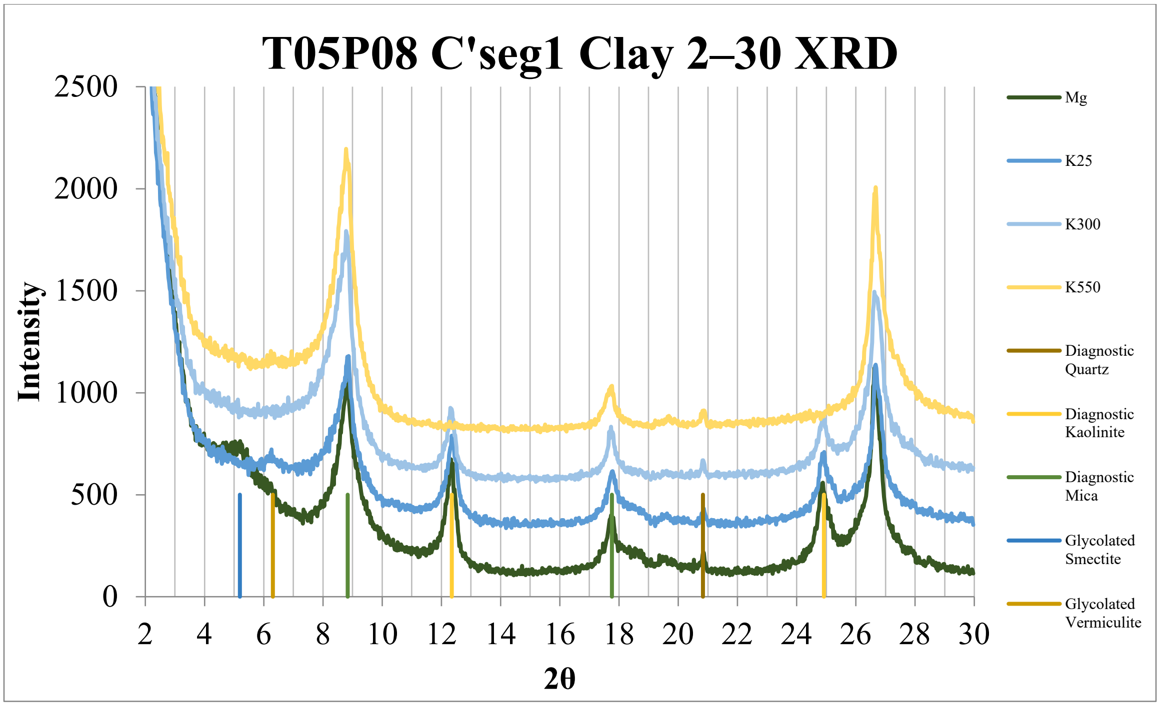
Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T05P03 Ase2 clay	X		XXX	XX	XX	X				



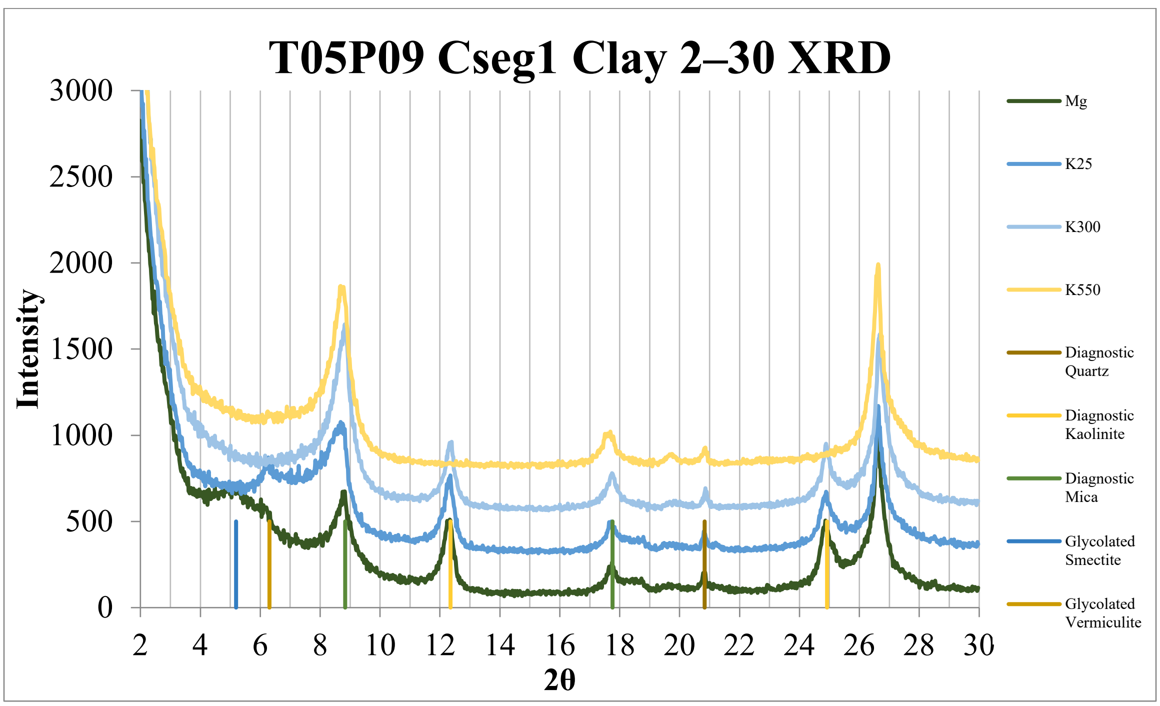
Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T05P08 Cseg1 clay	X		XXX	XX	XX	X				



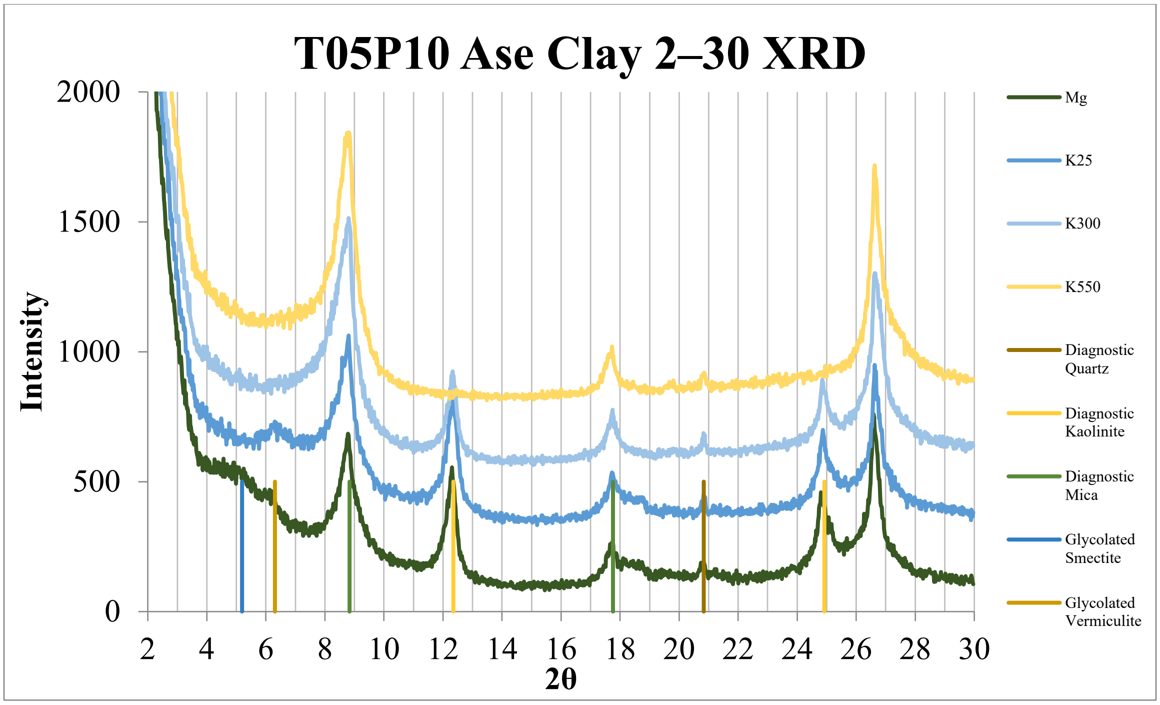
Sample	Quart	Feldspa	Kaolinit	Mica	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T05P08 ACg clay	X		XX	XX	XXX	X				



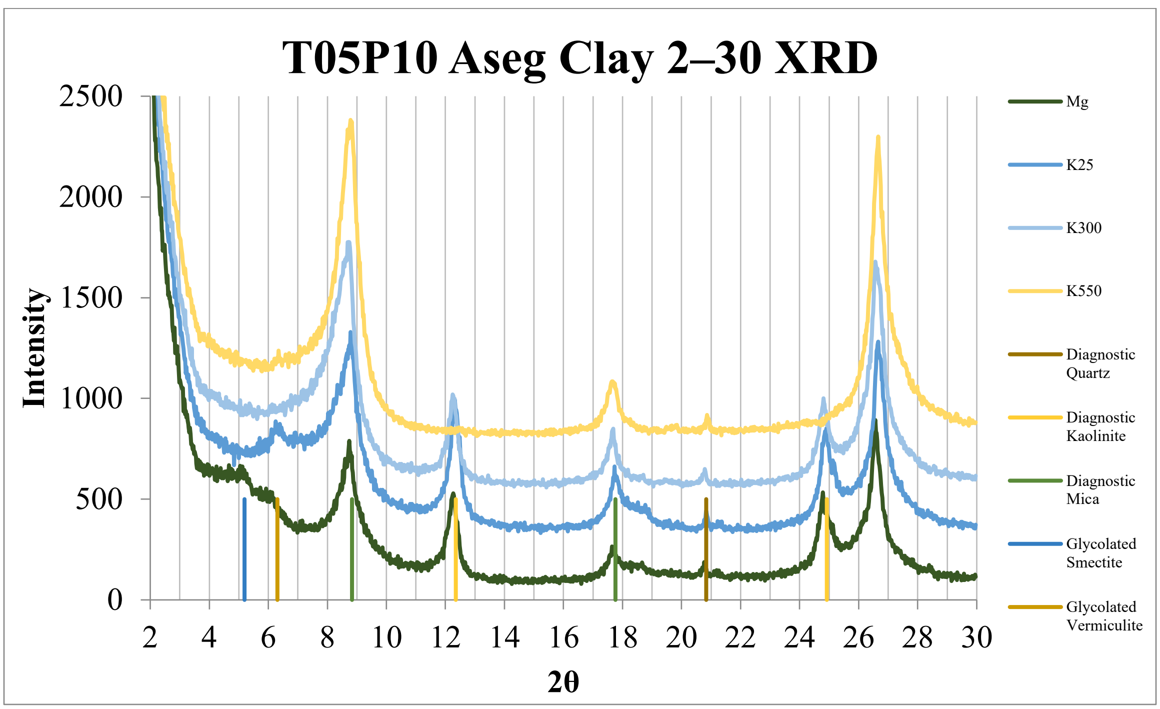
Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T05P08 C'seg1	X		XXX	XX	XX	X				



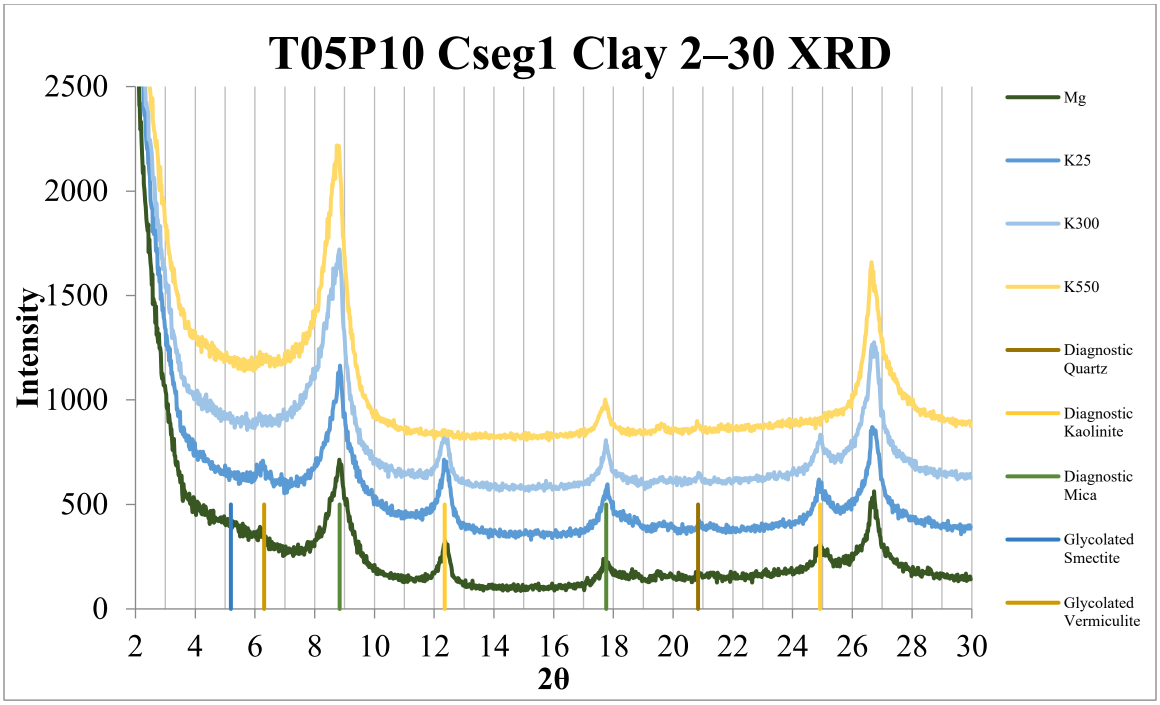
Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T05P09 Cseg1 clay	X		XXX	XX	XXX	X				



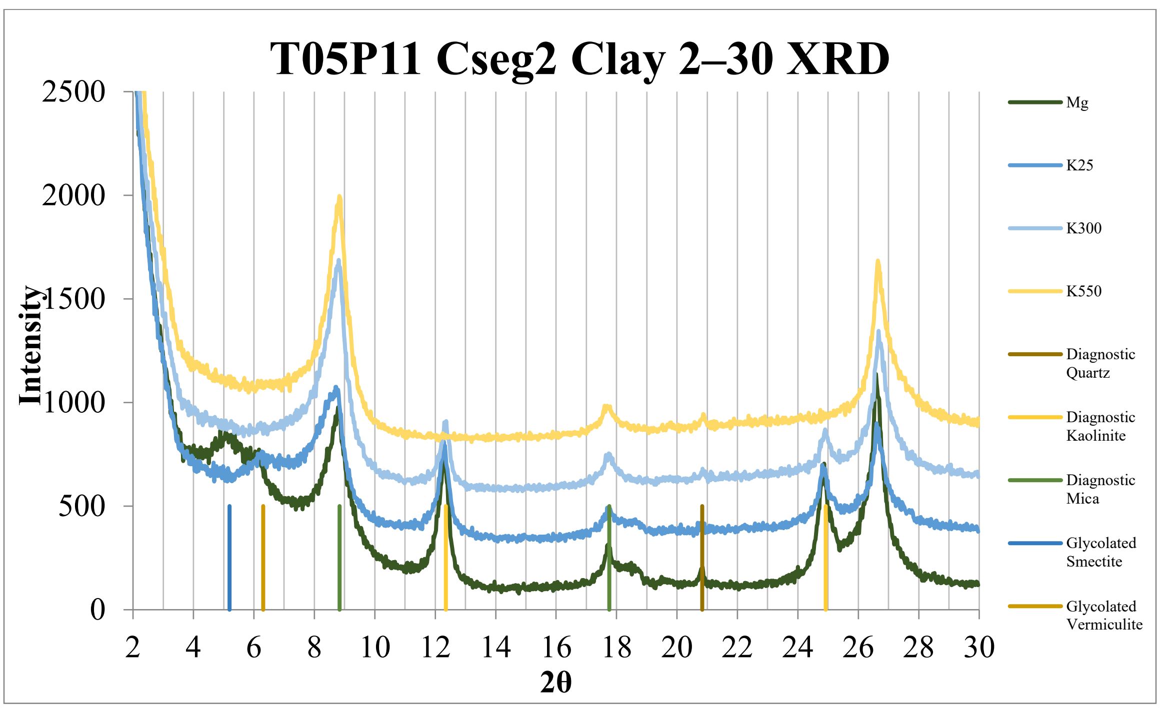
Sample	Quart	Feldspa	Kaolinit	Mica	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T05P10 Ase clay	X		XXX	XX	XX	X				



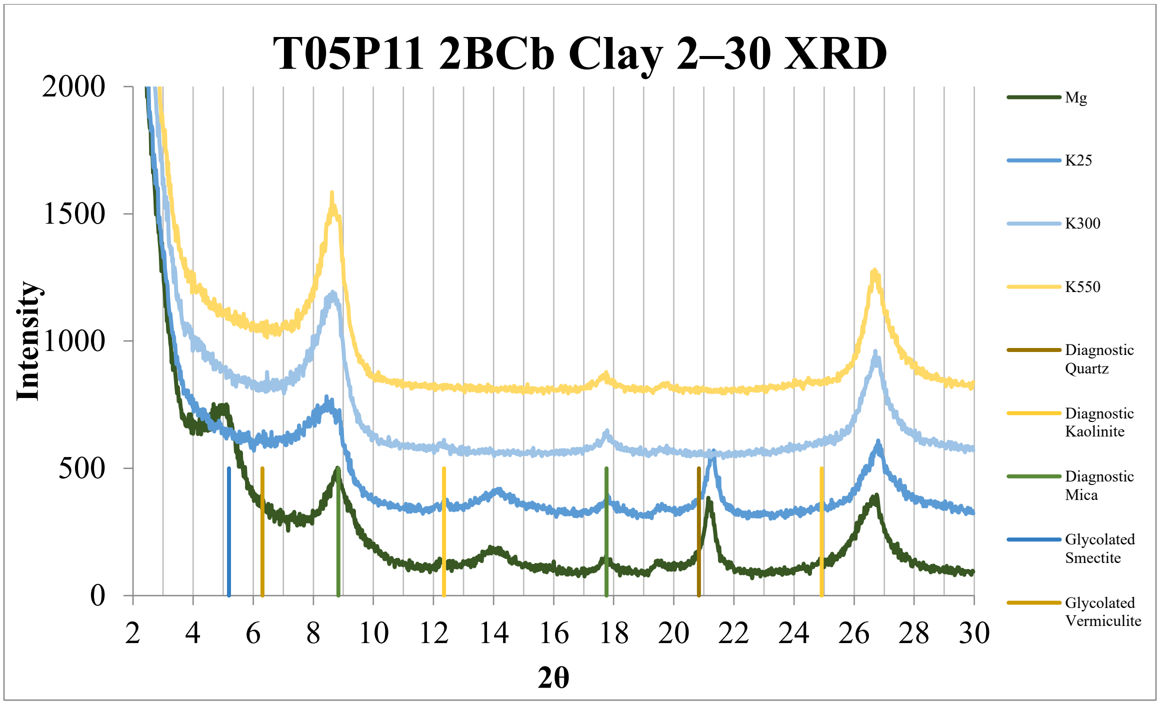
Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethite	Ilmenit	Pyrit	Hematit
T05P10 Aseg	X		XXX	XX	XX	XX				



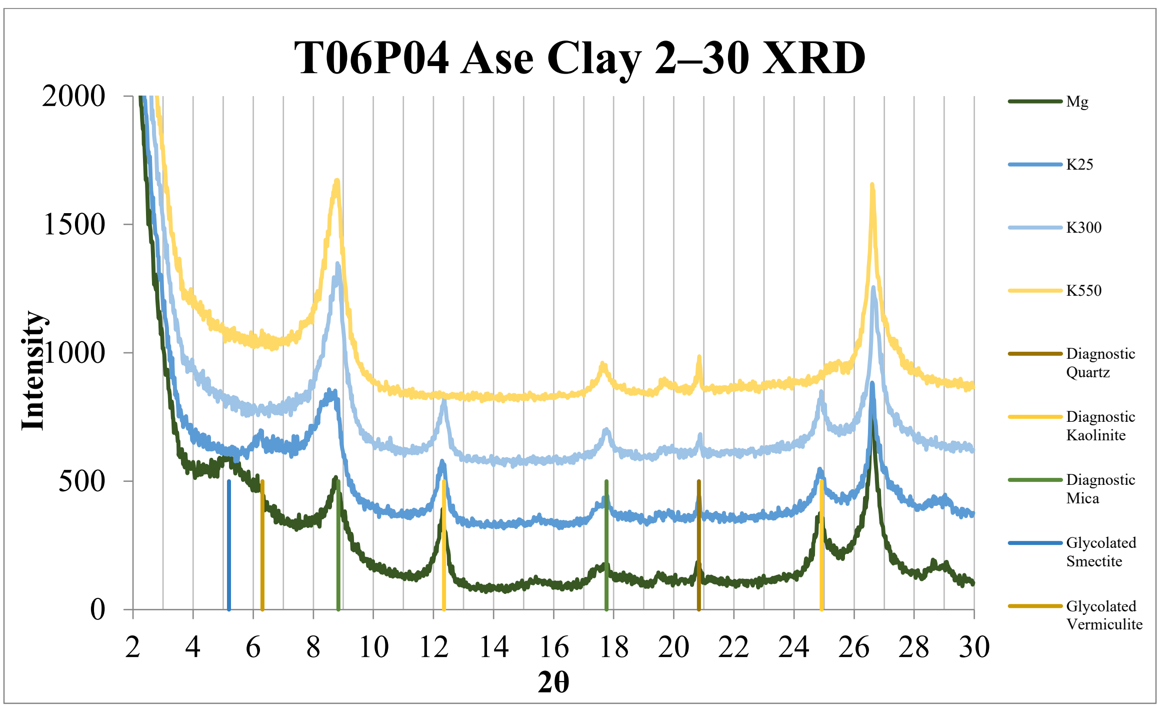
Sample	Quartz	Feldspar	Kaolinite	Mica	Smectite	Vermiculite	Goethite	Ilmenite	Pyrite	Hematite
T05P10 Cseg1 clay			XX	XXXX	XX	XX				



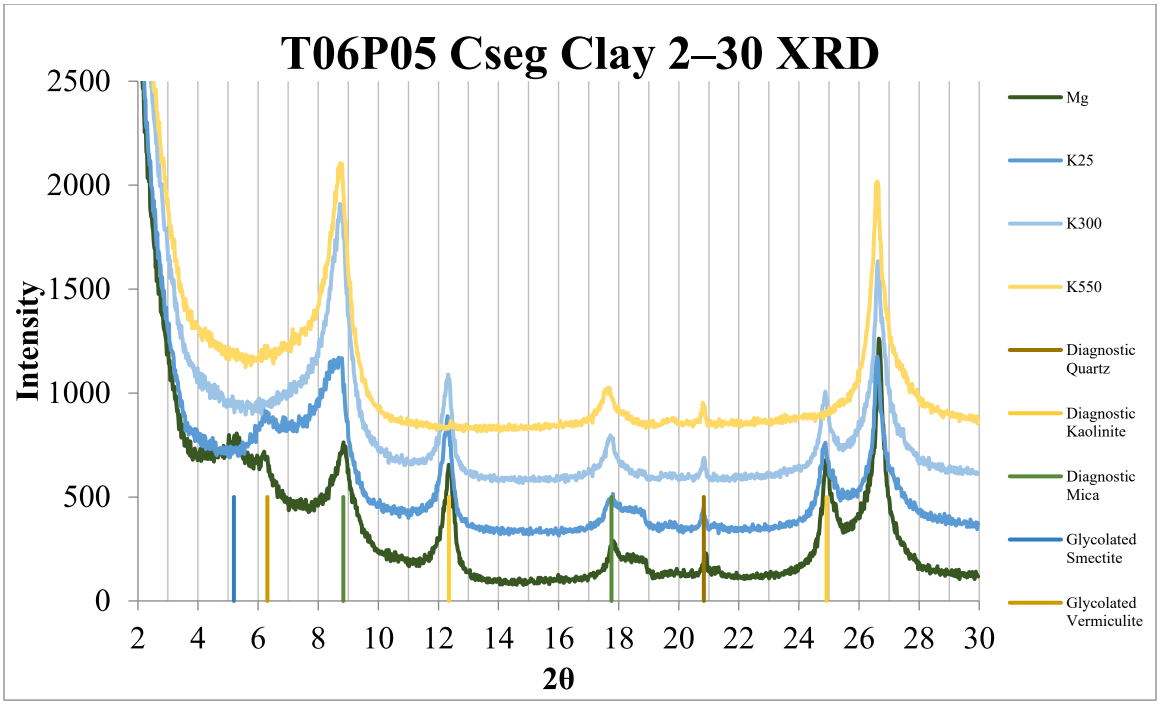
Sample	Quartz	Feldspar	Kaolinite	Mica	Smectite	Vermiculite	Goethite	Ilmenite	Pyrite	Hematite
T05P11 Cseg2 clay	X		XXX	XXX	XX	X				



Sample	Quart	Feldspa	Kaolinit	Mic	Smectit	Vermiculit	Goethit	Ilmenit	Pyrit	Hematit
T05P11 2BCb clay	XXX			XX	XXX	X				

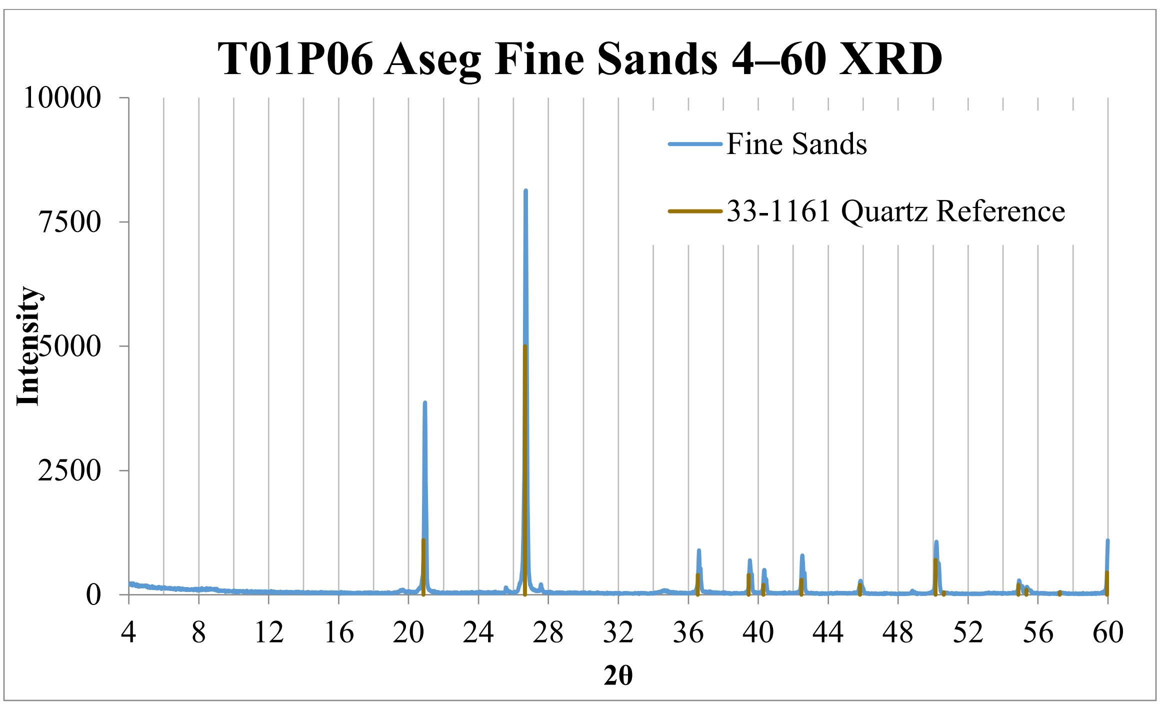


Sample	Quartz	Feldspar	Kaolinite	Mica	Smectite	Vermiculite	Goethite	Ilmenite	Pyrite	Hematite
T06P04 Ase clay	X		XXX	XXX	XXX	X				

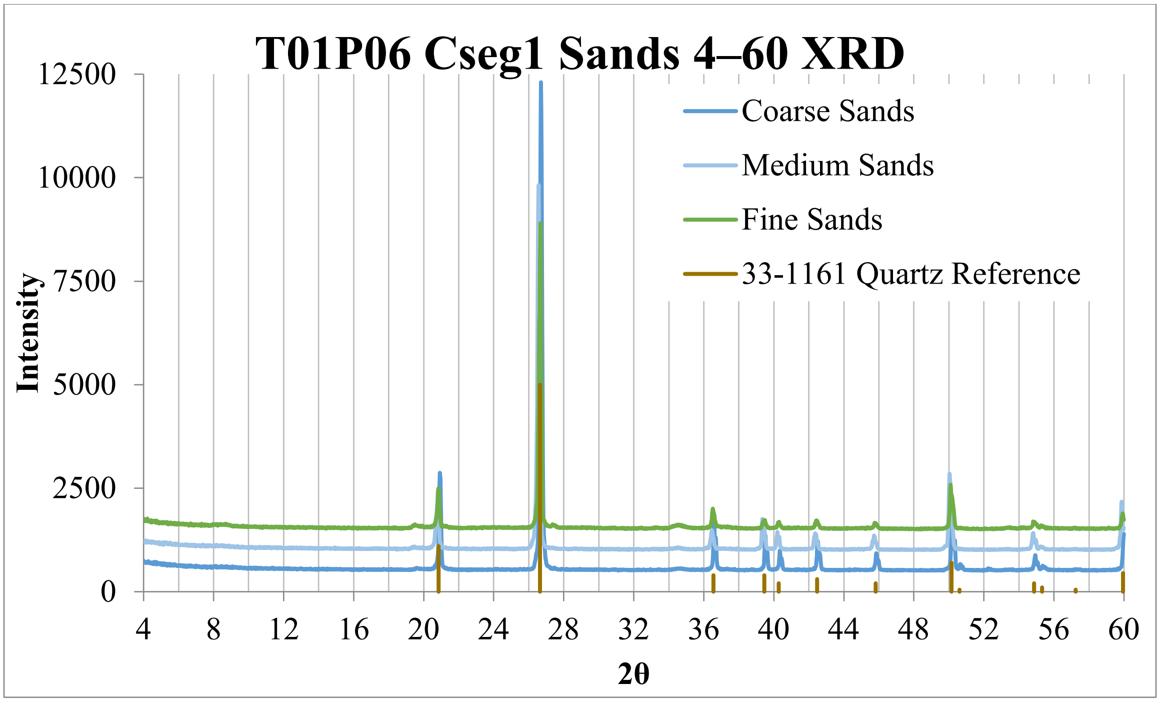


Sample	Quartz	Feldspar	Kaolinite	Mica	Smectite	Vermiculite	Goethite	Ilmenite	Pyrite	Hematite
T06P05 Cseg clay	X		XX	XX	XX	XX				

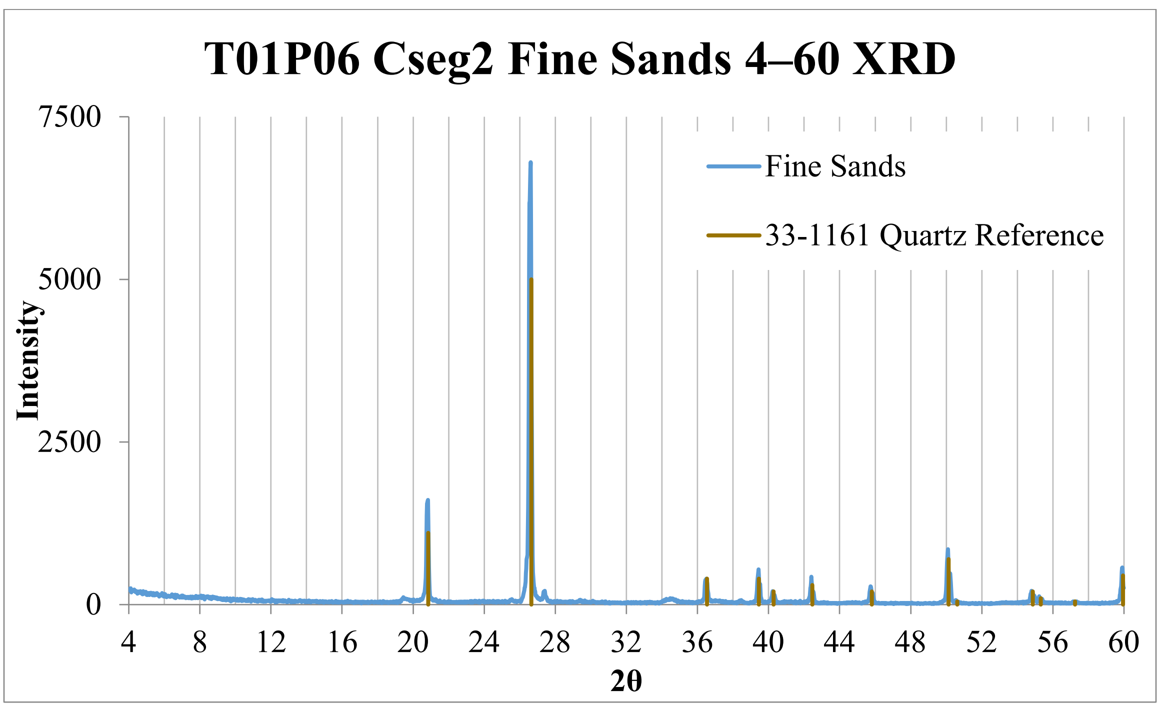
Sand XRD Spectra



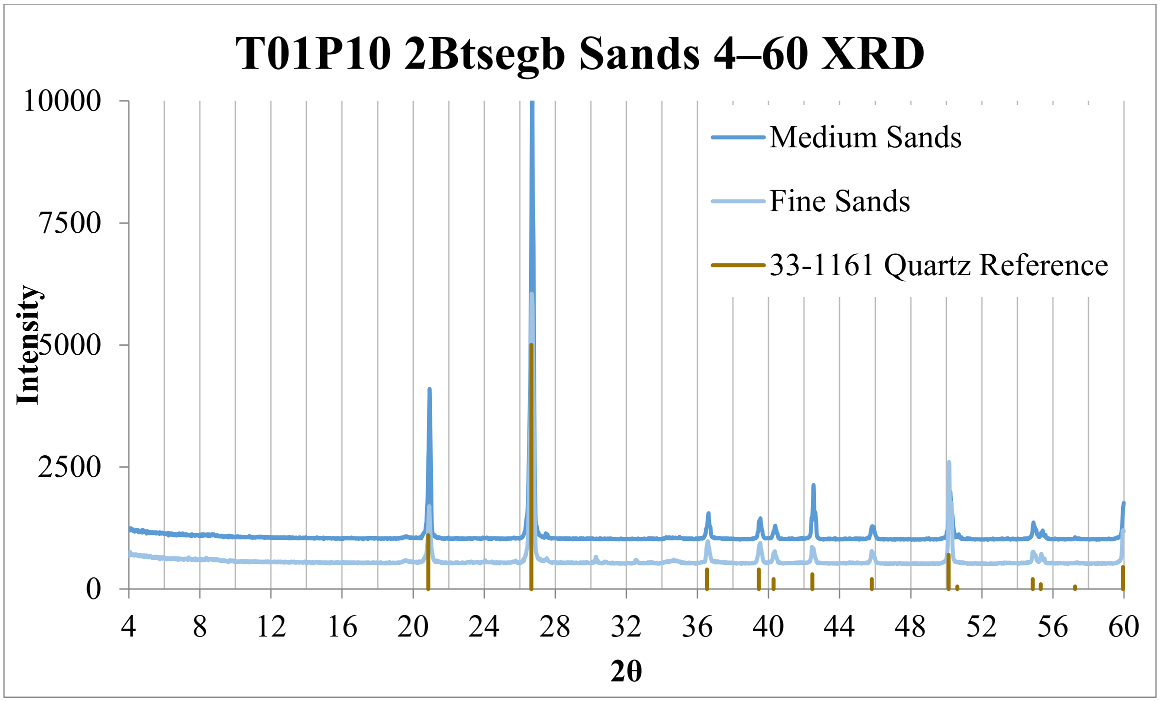
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T01P06 Aseg fine sand	XXXX	tr				



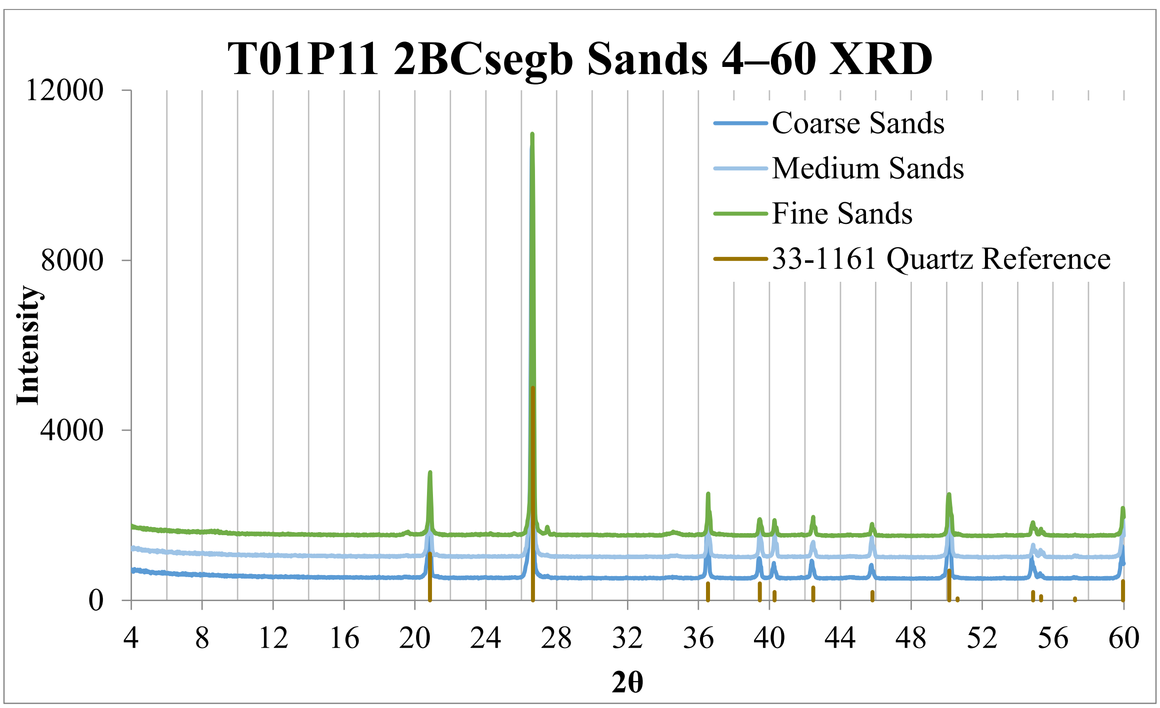
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T01P06 Cseg1	XXXX					



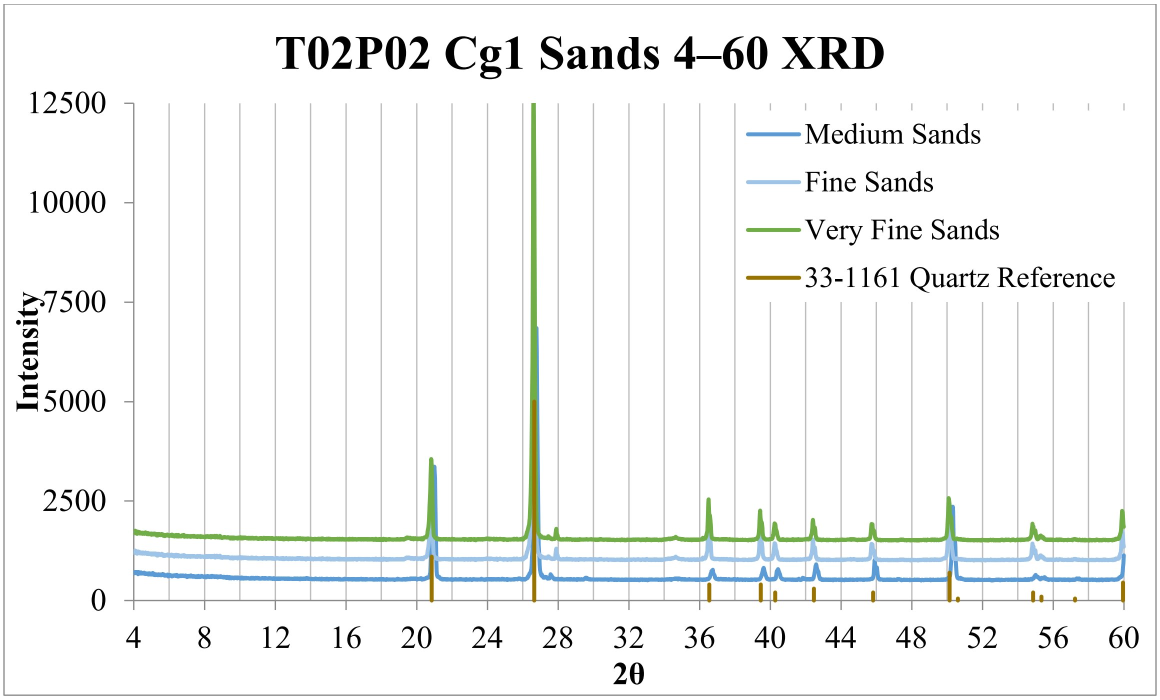
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T01P06 Cseg2 fine	XXXX	tr				



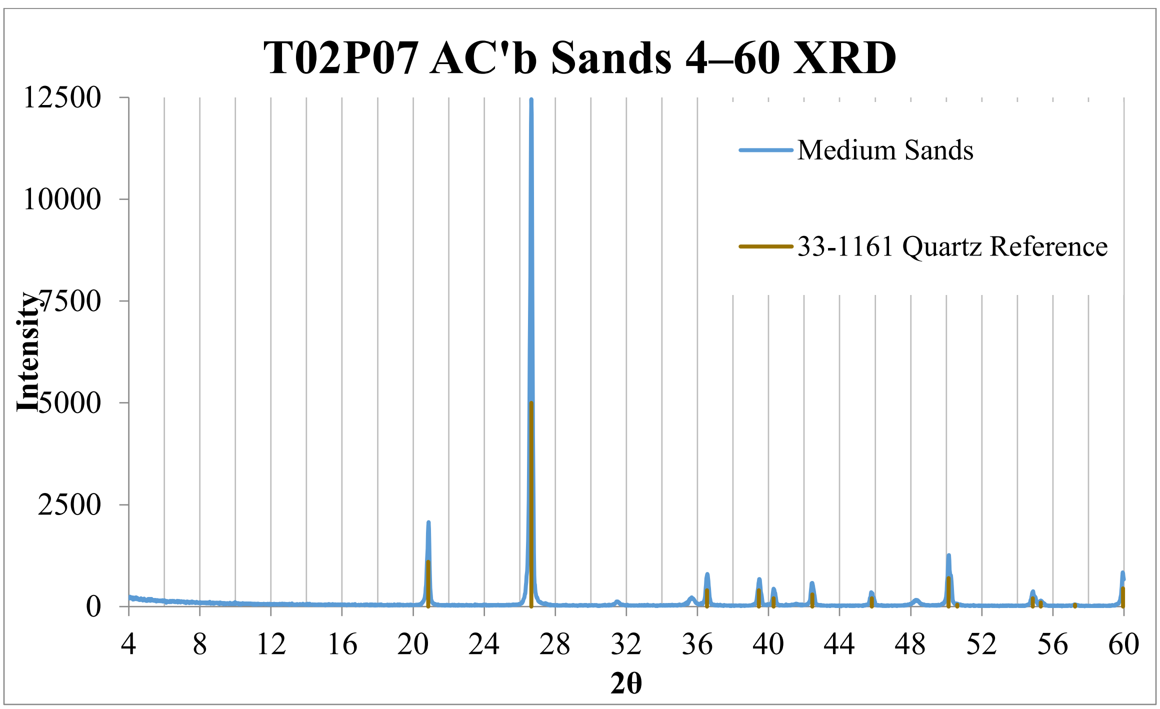
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T01P10 2Btsegb	XXXX					



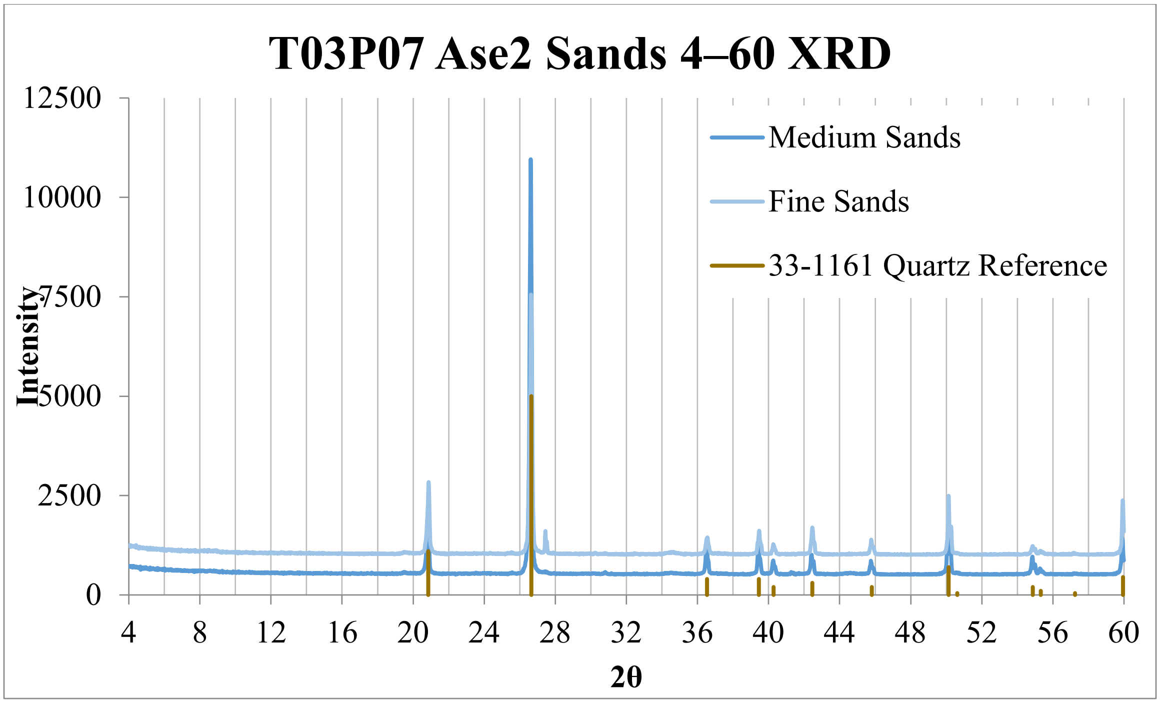
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T01P11 2BCsegb	XXXX	tr				



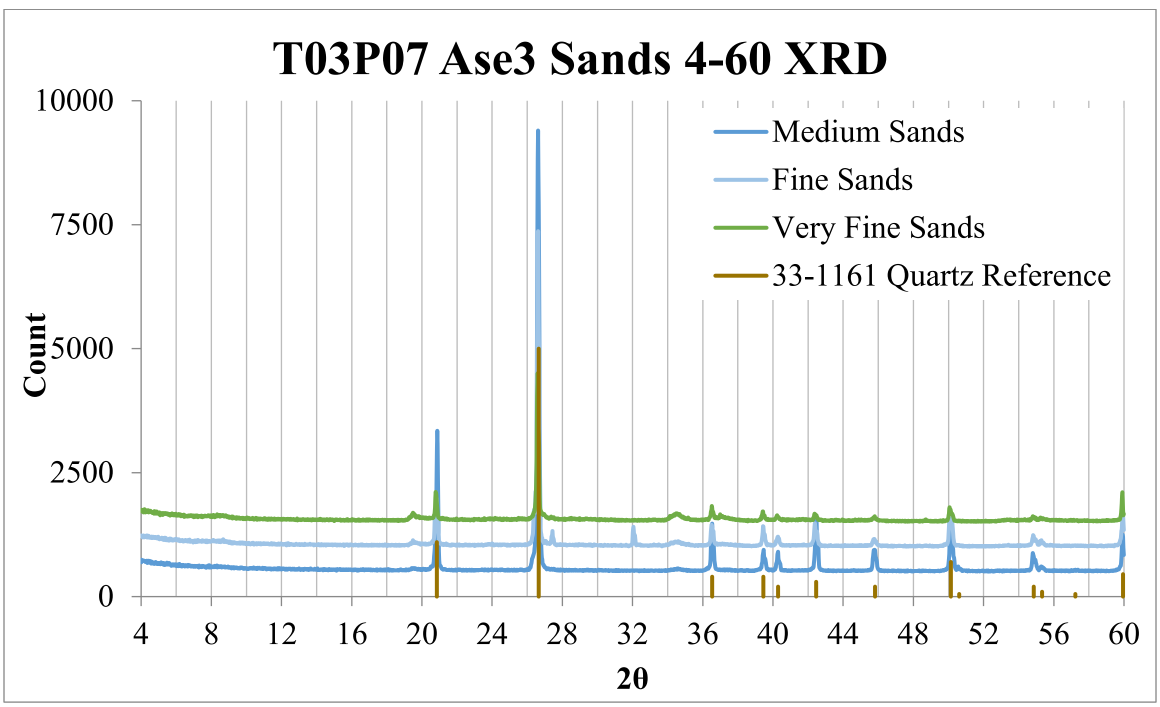
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T02P02 Cg1 sand	XXXX	tr				



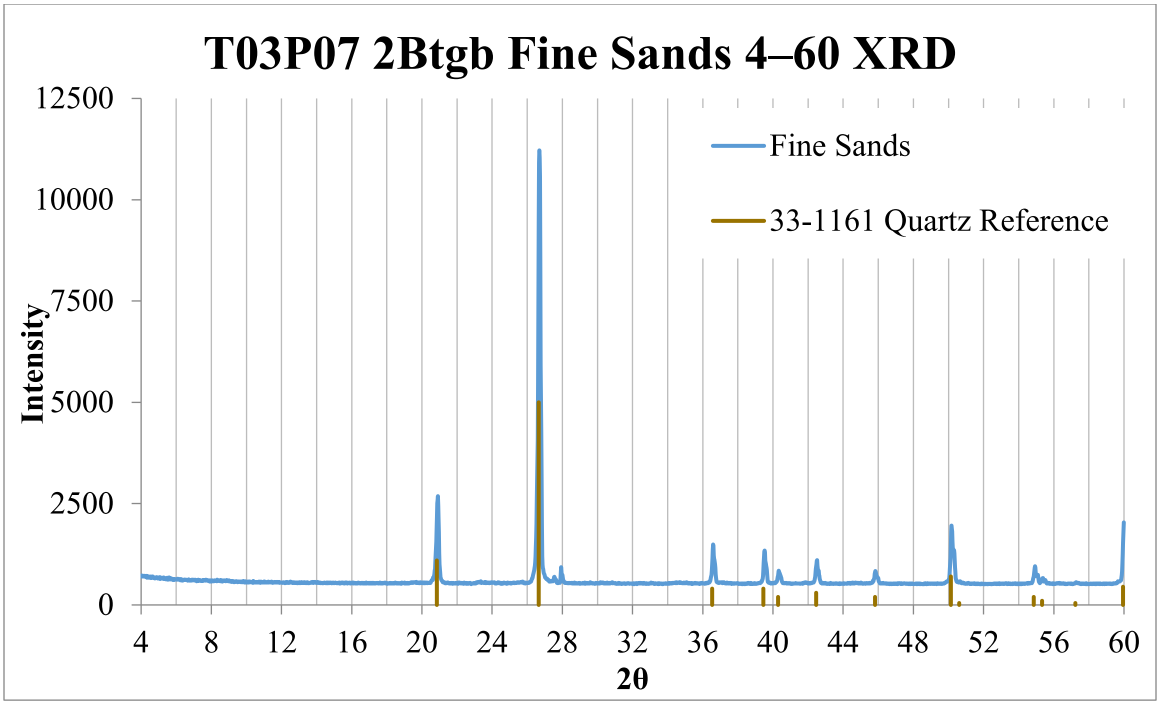
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T02P07 AC'b medium sand	XXXX					



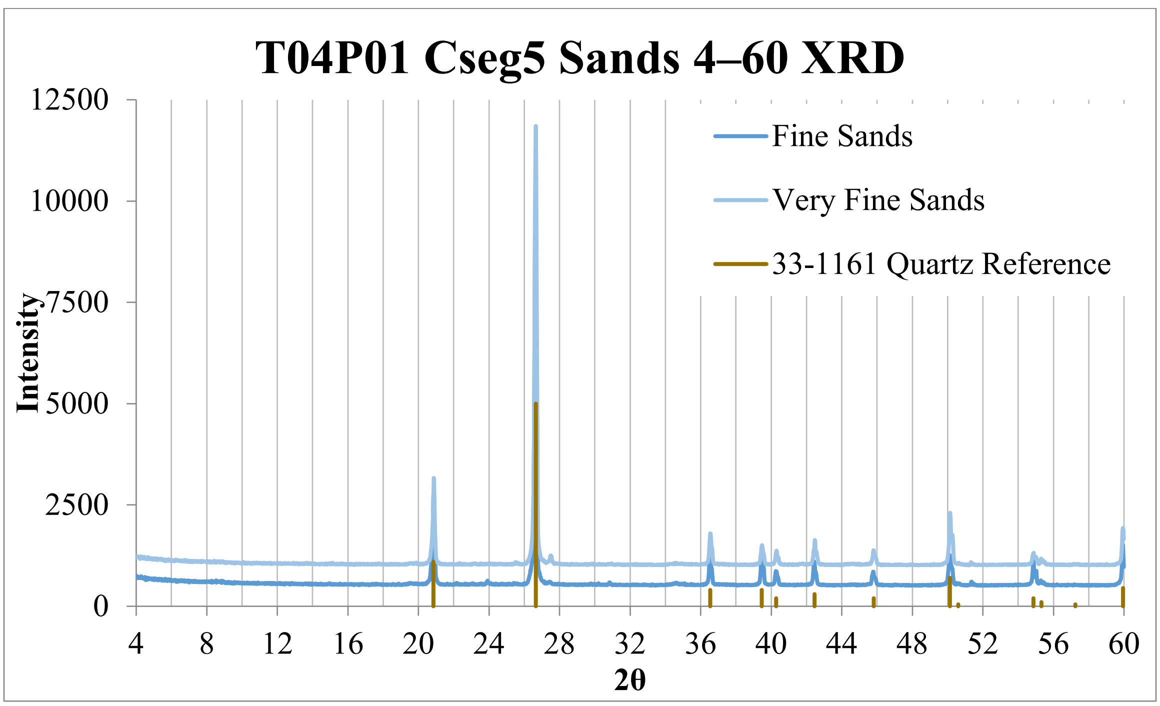
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T03P07 Ase2 sand	XXXX	tr				



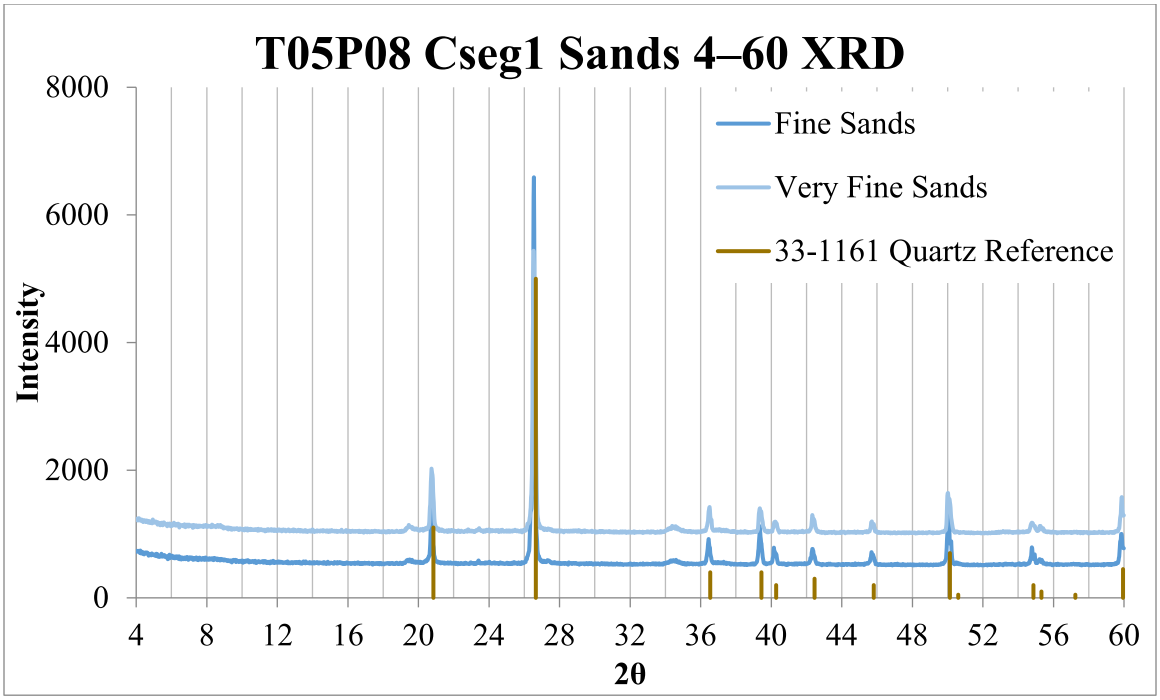
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T03P07 Ase3 sand	XXXX	tr				



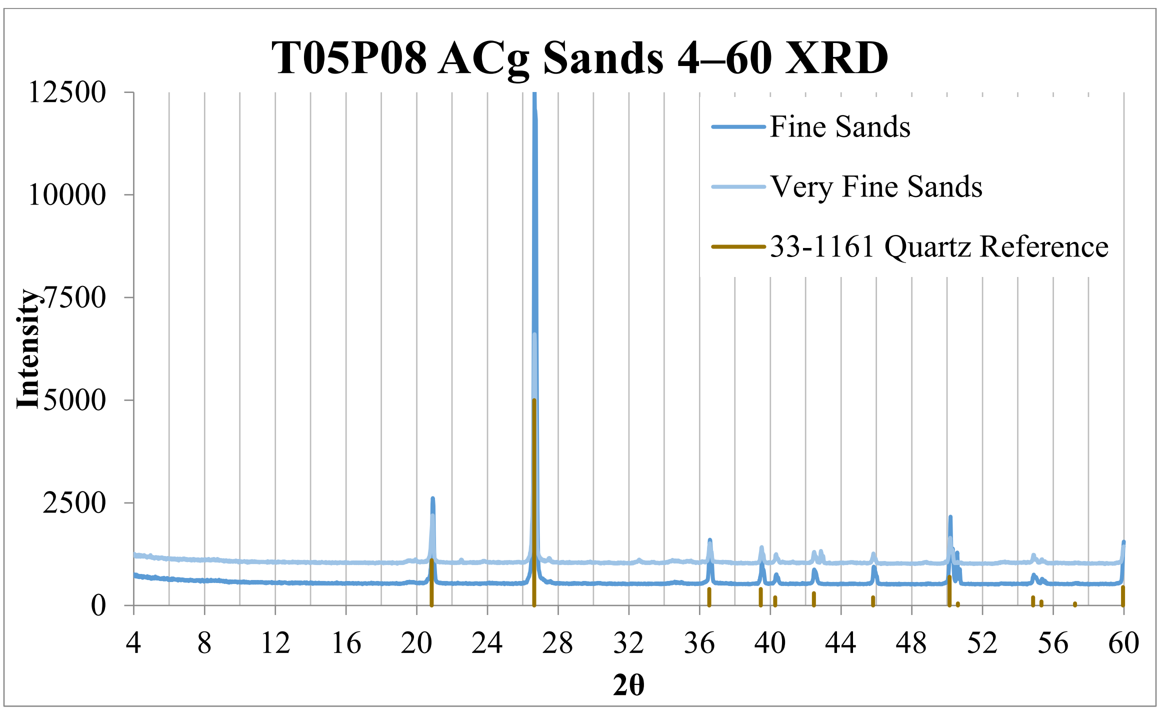
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T03P07 2Btgb fine	XXXX	tr				



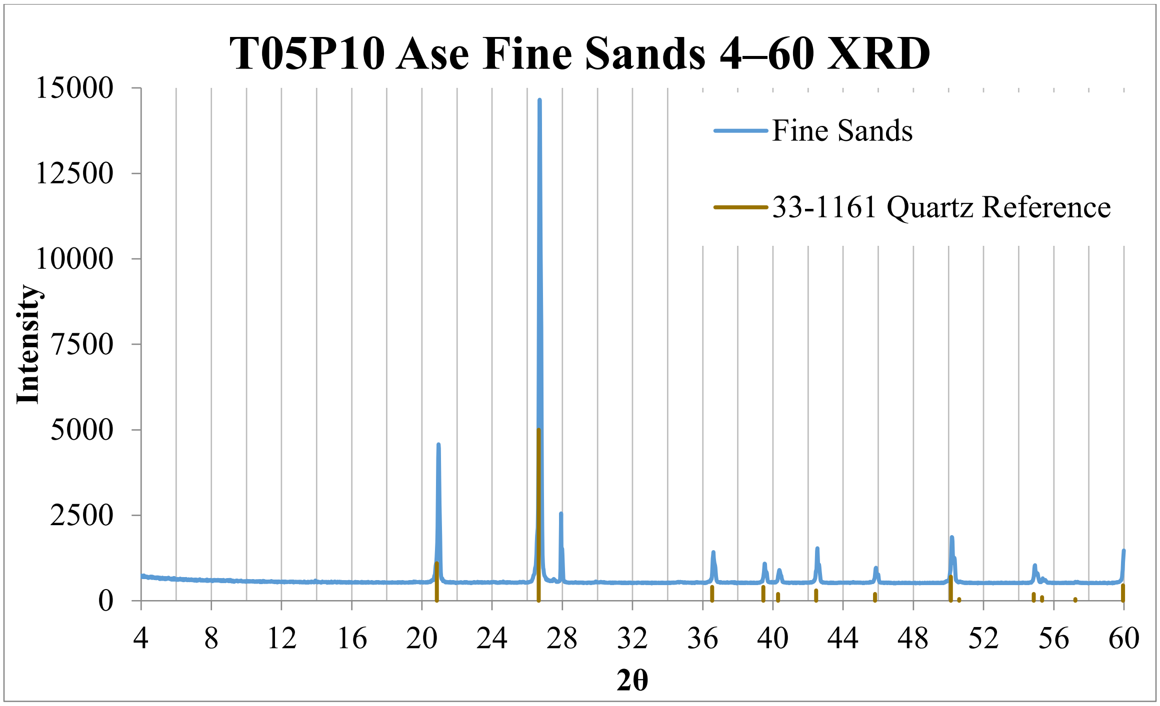
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T04P01 Cseg5	XXXX	tr				



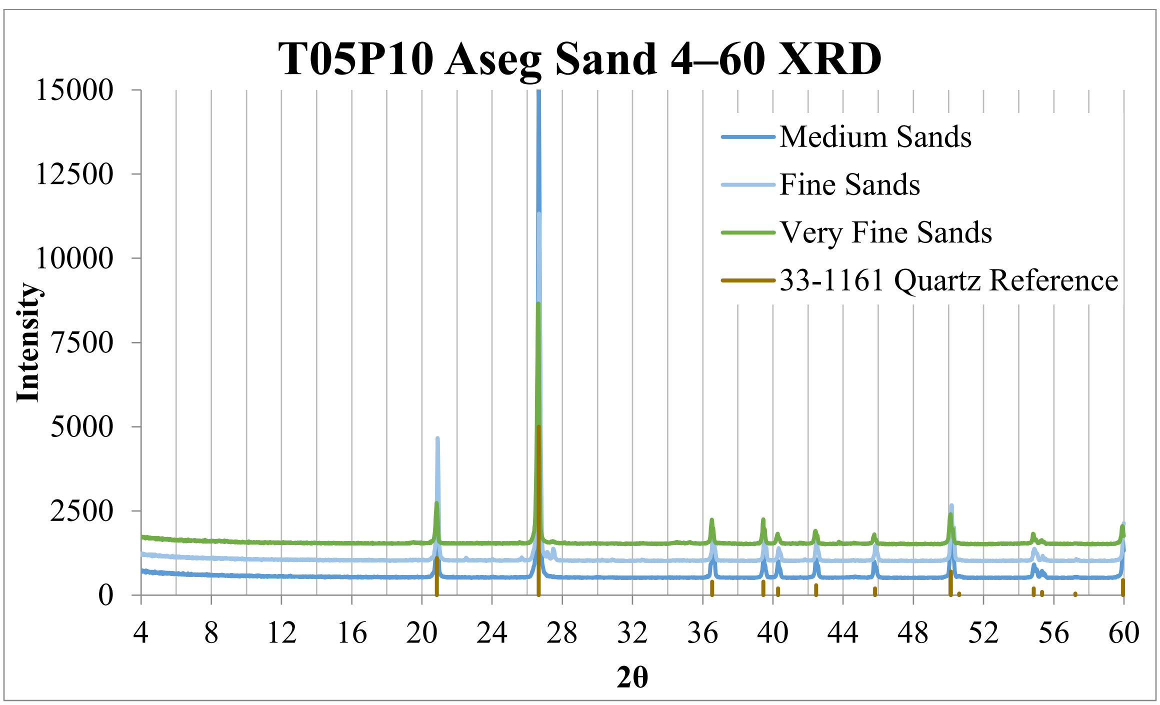
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T05P08 Cseg1	XXXX					



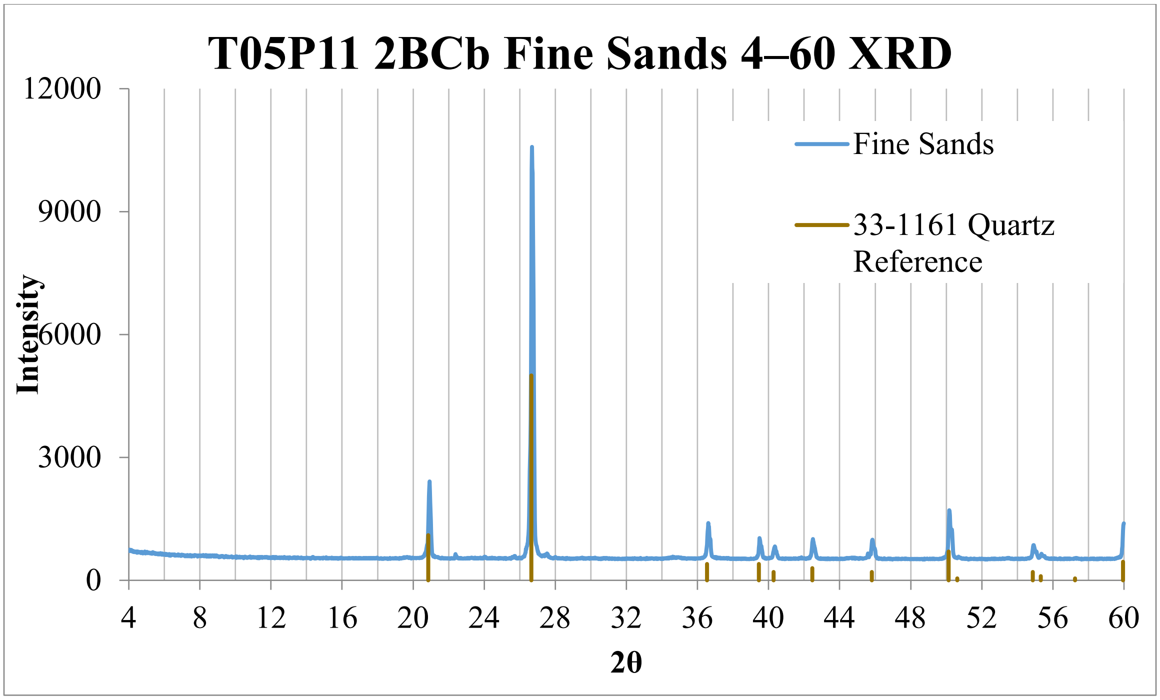
Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T05P08 ACg sand	XXXX					



Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T05P10 Ase fine sand	XXXX					



Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T05P10 Aseg sand	XXXX	tr				



Sample	Quartz	Feldspar	Goethite	Ilmenite	Pyrite	Hematite
T05P11 2BCb fine sand	XXXX					

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